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SECTION I

FROZEN FOODS

Gerald A. Fitzgerald, Associate Editor. Born 12/12/99, in Lynn, Massachusetts. Educated at Mass. Inst. of Technology, BS, 1923; M.I.T., 1923–24; George Washington University, 1926–27. Formerly, Graduate Research Asst. in Bacteriology, M.I.T., 1923–24; Asst. Technologist, U. S. Bureau of Fisheries, 1924–28; Research Engineer, General Seafoods Corp., 1928–30; Research Chemist, Birdseye Laboratories, 1930–34; Chief Chemist, 1934–38; Director of Quality Control, 1935–40; Director of Research, 1938–40; Member Operating Committee, Frosted Foods Sales Corp., 1938–40; Staff Asst., General Foods Central Laboratories, 1940–41; Technical Director, Richardson and Robbins Co., Dover, Del., 1942–45; Secretary and Managing Director, Frozen Food Foundation, Inc., 1945–50.

Author of numerous articles for trade papers and scientific publications; Associate Editor, Sec. I, 1946 Applications Volume, ASRE Data Books. Author of chapter on "Food Technology" in Engineering Opportunities, D. Appleton-Century Co., 1939.

Member of the Amer. Soc. of Refrig. Engrs.; Inst. of Food Technologists; Amer. Chem. Society; Amer. Public Health Assn. Awarded Certificate of Appreciation by Secretary of War, Robert P. Patterson, for "Valuable assistance and advice in connection with research and development of Quartermaster items" in World War II.

At present, Consulting Food Technologist, Fayetteville, N. Y.

1. THEORIES AND METHODS OF QUICK FREEZING

THE primary purpose of freezing perishable foods is to render them much less perishable without substantially altering their inherent freshness, thus permitting their prolonged storage and distant shipment. Rapid freezing offers the only presently available means for accomplishing this result without undesirably changing the form, flavor, and nutritive values of most kinds of perishables.

Since the commercialization of quick freezing in the United States, two distinct theories, known as the "mechanical" and the "physico-chemical," have been evolved to account for the beneficial effects of extremely speedy freezing. Neither of these theories by itself, however, can fully explain the essential phenomena. The true explanation lies in combining the facts set forth in both theories.

The Mechanical Theory

Both plant and animal tissues are composed of a multitude of individual cells in and around which is a complex liquid containing numerous mineral salts, vitamins, proteins, and other substances in solution or suspension. As the temperature of this liquid is brought below 32 F, numerous physical and chemical changes take place in it. One of the most important of these is the progressive formation of ice crystals as the temperature decreases. A very large percentage of the total water content is changed to ice crystals in the temperature range between 31 and 25 F, and this has become known as the "zone of maximum crystal formation." Thus, most perishable foods are frozen "hard" by the time their temperature has been lowered to about 20 F, and substantially all their free moisture has been solidified in the form of ice crystals at 0 F. Minute quantities of water, however, may continue to freeze out until the temperature of the product reaches about −70 F.

There is a fundamental difference between animal and vegetable tissues in that the **cell walls** of the former are reasonably elastic and so are not very readily pierced or broken by the formation of large ice crystals in the intercellular spaces. The cell walls of plant tissues, on the other hand, are composed largely of relatively **inelastic cellulose** and are therefore more readily damaged. For these reasons, plant tissues quick frozen by even the best commercial methods "bleed," wilt, and collapse to such an extent that some fruits and most vegetables do not make a satisfactory product unless cooked before being eaten.

The amount of water solidified at any given temperature is substantially the same whether the temperature drop is slow or fast. However, the size of the individual **ice crystals** varies inversely with the speed of the freezing, so that slow freezing results in the formation of a relatively small number of large ice crystals—crystals so large as to damage the tissues in which they are formed; whereas really quick freezing generates innumerable minute crystals within and between the individual cells in such a manner that the

CLARENCE BIRDSEYE, Author Chapters 1 and 2. Born 12/9/86 in Brooklyn, N.Y. Amherst College, Class of 1910; Honorary MA, 1941. Held the following positions: Field Naturalist, Biological Survey, USDA, 1910–12; Fur Trader in Labrador, 1912–17; Purchasing Agent, U. S. Housing Corp., 1917–19; Asst. to Pres. several companies pioneering quick freezing of dressed, packaged seafoods, 1923–29; Director of Research, Birdseye Laboratories, 1929–34; President, Birdseye Electric Company, 1935–38.

Author of several hundred scientific and technological magazine and newspaper articles; Chapters 1 and 2, 1946 Edition, Applications Volume, ASRE Data Books.

He is a Fellow of the American Society of Refrigerating Engineers; a member of the American Chemical Society, American Society of Mechanical Engineers, Mass. Horticultural Society, Quartermaster Association, Gloucester, Mass. Chamber of Commerce, New England Council; and has received the Babock Award, presented to him in 1949 by the Institute of Food Technologists on behalf of Nutrition Foundation.

He is at present President and Director, Mechanical Research, Inc., and Dehydration, Inc.; Director Cape Ann National Bank; Inventor and Consultant in the food freezing and dehydration fields, since 1939; Consultant to General Foods Corporation; and on the Technical Advisory Board of the Quick Frozen Foods magazine.

tissue is not greatly damaged physically. (See Chap. 2, page 12.)

The Physico-Chemical Theory

During the time that the water is being changed into ice in tissues being frozen, the dissolved salts form more and more concentrated solutions. This results in a chemical salting out effect in which the soluble proteins are rendered less soluble and may precipitate from solution. This phenomenon may be partly physical, the tendency being for the concentrated salts to dehydrate the protein by osmosis. If the protein can no longer reabsorb its original moisture, it is then said to be irreversibly or chemically denatured.

Moran[2] intimated that fast freezing may result in congealing the colloidal sol both within cells and in the intercellular fluids of tissues. In the example given by him, fast freezing of a gelatin solution resulted in solidifying the gel while slow freezing caused its destruction. On thawing, the quick frozen gelatin tends to return to the state of a thin gel, but the defrosted slow frozen material consisted of partially dehydrated gelatin and water.

The **protective colloid theory**, which has been well substantiated in numerous physiological and biochemical studies, sufficiently explains the above reversible-colloid phenomenon. This theory indicates that colloidal sols naturally resist breakdown because each sub-microscopic colloidal particle is surrounded by a protecting envelope that stabilizes it against the coagulating and dehydrating power of electrolytes (mineral salts in solution). The envelope around each colloidal particle is called a protective colloid.

The protective colloid serves effectively to prevent loss of water from the colloid by osmosis, so that if ideal freezing conditions were available the cell tissues would merely jell without chemical dehydration and on thawing would resume their natural form. In practice, however, even the quickest commercial method of freezing leaves much to be desired. Conversely, even the slowest freezing cannot cause complete chemical dehydration of the colloidal cell contents.

Storage Conditions

Frozen foods should be held at 0 F or lower, with a minimum of temperature fluctuation, and in a relatively humid atmosphere. Under such conditions, both chemical and physical changes in the product are minimized.

Low storage temperatures are essential for several reasons. Chemical and enzymic changes are reduced greatly at lower storage room temperatures. Vapor pressure in the product correspondingly decreases with lower temperature, and evaporation of moisture from the product is thereby lessened.

For much the same reasons storage room temperature must not be allowed to fluctuate more than absolutely necessary. To the extent that such fluctuations raise and lower the temperature of the stored product, ice crystal size will increase by accretion and the product will be damaged both physically and chemically. (See Table 1.)

Table 1. Effect of Temperature on Percent of Water Frozen out of Meat.[2(b)]

Temp.	% Water Frozen Out
29.3	35.5
28.4	55.5
26.6	69.8
23.0	81.6
19.4	88.7
14.0	94.0
− 4.0	98.2

High relative humidity in storage rooms cooperates with low temperatures to reduce loss of moisture from the product.

Freezing speeds are relative, and because some products (generally those containing a very high percentage of water) require faster freezing than others, it is difficult to formulate a satisfactory definition of quick freezing. Commercially speaking, however, a quick frozen product is one which has been frozen so rapidly that it is not greatly changed by the freezing process.

History of Food Freezing

Perishable foods were first frozen commercially in the United States by artificial refrigeration about 1875, when the freezing

of fish and meats began to take place in crude rooms insulated with sawdust and cooled by means of ice and salt. Frozen meat was first shipped from the United States to England in 1876 and from Australia some five years later.

About 1890, mechanical refrigerating apparatus came into wide use in both Europe and North America and gave a tremendous impetus to the freezing and cold storage of foods. By the early 1920's, frozen meats, poultry, and seafoods were so extensively used in many of our large cities that great hardship would have resulted if cold storage foods had suddenly become unavailable.

Fruits were first frozen commercially, usually in the containers in which they had been shipped to wholesale markets, in the Eastern states in 1905. In 1910 fruit freezing was undertaken on a substantial scale in our Pacific Northwest states, where the product was mixed with sugar and frozen in large containers, mostly 450-lb barrels. This bulk frozen fruit became known as "cold pack."

Fully-dressed, ready-to-cook fish were first quick frozen in the United States in 1924, in New York City.

An integrated line of retail packages of dressed meats, poultry, seafoods, fruits and vegetables was quick frozen in Massachusetts and Oregon in 1929 and initially marketed in Springfield, Mass., in the spring of 1930.

More than 100 different kinds of quick frozen cooked foods were developed by the Birdseye Laboratories at Gloucester in 1932–1934, but this type of product was not marketed extensively until 1943.

Types of Freezing Apparatus

During the last score of years there has been a progressive recognition of the advantages of freezing perishable foods as rapidly as commercially practicable. This revolutionary tendency toward quicker freezing has brought about the development of a large number of quick freezing methods of widely different types and simultaneously has narrowed the time gap between "sharp" and "quick" freezing.

Accurate classification of freezer types is not possible, for the several forms overlap in many respects; but for the purpose of this study they have been arbitrarily grouped into "convection" and "conduction" apparatus.

Convection freezers are those in which heat is removed from the product and conveyed to the refrigerating surface principally by either natural or mechanically-induced convection currents of low-temperature air. Conduction freezers are, conversely, those by which heat is transferred directly or indirectly from the product to the refrigerant preponderously by means of conduction.

Convection freezers. "Sharp" freezers are, essentially, well insulated rooms maintained at low temperatures. In them, heat from the product passes first to the air of the room and is then carried to refrigerating coils by convection currents. One very common type of sharp freezer consists of an insulated room with expansion coils located on the walls or ceiling or both. Another sort of sharp freezer has expansion coils (or plates) in the form of tiered shelves upon which the product is placed while being frozen. This type of freezer removes heat from the product by both conduction and convection. Either of these types of sharp freezers may employ mechanically-induced convection currents to speed freezing. Both should be very heavily piped, possibly 1 sq ft of surface to 2 to 4 cu ft of space. They must not be overloaded with warm product. For application of plates, see Chap. 36, page 313, (Locker Plants).

"Air-blast" freezers differ from sharp freezers in that they are usually in the form of tunnels and are designed to take full advantage of the heat-transfer capabilities of rapidly circulated air. Such freezers are widely used to produce a great variety of quick frozen foods of excellent quality

Unfortunately, air-blast freezers have several inherent disadvantages. In the first place, such freezing may not be so rapid as freezing between heat-conductive refrigerated plates or by immersion in very cold liquid refrigerants. Furthermore, except in the most modern types of air-blast freezers, much moisture may be lost from unpackaged products. This evaporation is due fundamentally to too great tempera-

ture differentials between the cooling coils and the air currents and between the air currents and the product during the initial stages of freezing. In many of the cruder blast freezers this evaporation amounts to from 5 to 8 per cent of the weight of products such as shelled peas, and almost wholly removes the protective film of surface water, thereby enhancing the danger of "freezer burn" during subsequent storage. Moreover, even a 5 per cent moisture loss from material having a value of 15 cents a pound may amount to much more than double the cost of actually removing the heat from the product. Water evaporated from the product is deposited as frost on the expansion coils of the system and necessitates frequent defrosting. Additional well-recognized disadvantages of air-blast freezing are bulged containers of pre-packaged product, less compact packaging of "loose frozen" foods, and the necessity for using very low air temperatures.

The **tunnel type** of air-blast freezers apparently originated in Canada (Beard) about 1930, when a freezer was built to carry fish on a solid metal belt through a wind tunnel. The principal development of this type of freezer, however, has been in the Pacific states, where the product is usually carried through the freezing zone on wire mesh belts. There are a great many different types of tunnel freezers, no two of the installations being exactly alike.

A relatively modern development of the air-blast freezer was initiated by Finnegan and has as its primary objective control of evaporation from the product. This is accomplished by carrying out the freezing process in **successive stages,** with the temperature of the cooling coils and of the air in each stage proportioned to that of the product. A typical freezer of this type consists of an anteroom for precooling, one or more freezing stages, and a final tempering area. The product is carried in trays on wheeled trucks. Apparatus of this general type is now manufactured by several well-known concerns. For instance, the Frick "Blizzard Freezer" and the "York Continuous Fast Freezer." Another freezer designed to avoid moisture loss is the Greene Freshet or progressive system in which the product is frozen continuously in trays moving vertically. Freezing is done in two stages.

A very different type of convection apparatus is the Knowles "shaker" freezer, manufactured by the Northwest Baker Ice Machine Company. In this equipment the product passes downward over a succession of superposed perforated shaker platforms while very cold air is forced through and over it at high velocity. This may be used as a pre-freezer, the final freezing being done by any suitable means such as the Knowles Bazooka Freezer, a refrigerated tube housing a refrigerated screw conveyor.

The need for a completely mobile freezing unit was met in 1947 through the cooperative efforts of the Tennessee Valley Authority, the G. M. and O. Railroad and the Merchants Dispatch Transportation Corporation. Mounted over standard railway carriages, the twin-car unit, having a capacity of 2000 lb per hour is designed to serve one-crop areas having short operating seasons which would not otherwise justify investment in satisfactory freezing equipment. The design is essentially that of a compact air-blast unit.

Conduction freezers. Conduction freezing is carried out in two distinct types of apparatus. One, comprising "direct-contact" freezers, subjects the product directly to an edible liquid refrigerant. The other, usually referred to as "indirect-contact" freezer, places the product in contact with refrigerated metallic surfaces.

Direct-contact apparatus afforded one of the earliest means of quick freezing. In this type of freezer, the product is showered with, or immersed directly in, a low-temperature solution of sodium chloride brine or other secondary refrigerant. The advantages of this method are obvious—rapid freezing and the ability to bring the refrigerant into intimate contact with all parts of an irregularly-shaped object. The disadvantages, however, have been so serious that this method is today used for producing only a small part of the total production of frozen foods.

Osmosis is the principal cause of trouble. If brine is used as the secondary refriger-

ant, salt penetrates the food and catalyzes undesirable changes during storage. If sugar syrups are employed, penetration into the product is usually not detrimental and may, in the case of many fruits, be highly desirable. But **osmosis** extracts juices from the food, contaminates and dilutes the refrigerant, and necessitates frequent purification thereof. Most refrigerants suitable for use in this process are so viscous at low temperatures that they are difficult and expensive to circulate at the necessary velocities.

The earliest direct-contact apparatus used in the United States was introduced from Europe in 1918 and was known as the Ottesen brine freezer. It was designed to use an eutectic sodium chloride brine (23 per cent), but in commercial use this ideal concentration could not be maintained. Therefore brine penetrated the product and seriously diminished its storage life.

Harden F. Taylor in 1923 patented a continuous tunnel-type **spray freezer** in which whole fish were first passed through a shower of fresh water, then through a spray of sodium chloride brine at about 10 F, and finally through a second fresh-water shower which was supposed to wash off the surplus brine and place an ice glaze on the frozen fish. Later this apparatus was used to freeze fish fillets in tin cans and blocks of fillets in aluminum molds.

M. T. Zarotschenzeff patented his **"fog freezer"** in the United States in 1933. In its original form, this apparatus consisted of a cabinet, on the shelves of which fish and other products were bombarded with a "fog" of sodium chloride brine particles and air at near-zero temperatures. Largely because of the difficulty of atomizing sodium chloride brine, the "fog freezer" was never extensively used in the United States. Later, however, the Zarotschenzeff freezer was modified to employ a coarse spray or shower of either sodium chloride brine, sugar syrup, or a mixture of both.

R. B. Taylor, an employee of the Tennessee Valley Authority, about 1939 developed an **immersion freezer** primarily for vegetables and small fruits. This apparatus consists of an insulated tank containing from 2000 to 4000 gal of invert sugar syrup maintained at about 8 or 10 F. Comestibles to be frozen are carried through this syrup by a wire mesh conveyor. Articles the size of strawberries are frozen in from 6 to 10 min. After the products have emerged from the tank, the excess syrup adhering to them is removed by centrifuging.

Luis H. Bartlett and W. R. Woolrich of the University of Texas about 1940 developed the Bartlett **"polyphase"** quick freezing apparatus, in which the food to be frozen is mechanically passed through a slowly circulated liquid edible refrigerant maintained in a "slushy" condition by the presence of minute ice crystals. Sodium chloride brine has been used as the medium for freezing shrimp, and syrups containing invert sugar have been employed for fruits and vegetables.

Indirect-contact freezers are likewise very old and include such early apparatus as ice cream freezers and the cans used in making artificial ice. There follows a brief description of some of the more interesting forms which have been used during the last 25 years.

Paul W. Petersen in 1921 developed an apparatus for freezing perishables while packed in a narrow, tapering metal can submerged in a liquid refrigerant. The apparatus was used commercially for freezing whole or partially-dressed fish.

Clarence Birdseye in 1924 used a compartmented metal container submerged in calcium chloride brine to produce the first quick frozen fish fillets.

Robert E. Kolbe in 1923 developed his **"diving-bell"** freezing process, by which comestibles were packed in pans with telescopic covers and frozen by submerging the cans in a liquid refrigerant. In 1925 Kolbe developed a method of freezing fish fillets and other comestibles by conduction from one side and convection from the other by placing the fillets on the bottom of a metallic pan floating along a predetermined path on a current of calcium chloride brine.

A. H. Cooke in 1927 developed a **"floating-plate"** fish freezer consisting of flat, heat-conductive metal plates mechanically passed over, and with fins projecting into, a tank of liquid refrigerant.

Clarence Birdseye in 1926 built his first **"double-belt"** quick freezing apparatus, which consisted of superposed metallic endless belts passing through an insulated tunnel and so arranged that the upper run of the lower belt and the lower run of the upper belt carried packaged or unpackaged products pressed between them through the tunnel while calcium chloride brine at −45 F was sprayed against the under side of the lower belt and the upper side of the top belt. This apparatus for the first time made it possible to quick freeze fresh foods continuously in small rectangular packages by conduction from both sides. In 1930 Clarence Birdseye and Bicknell Hall developed the "multiplate" quick freezer, in which packaged products are frozen from both sides while interleaved between movable heat-conductive refrigerated plates which are mechanically separated while the product is being inserted or removed, and pressed into firm contact with the product while freezing is taking place. (See Chap. 3, page 20.)

The demand for loose-frozen products such as are produced in many of the air-blast freezers, led Birdseye to invent a continuous loose freezer of the contact type called the Gravity Froster. This can handle large volumes of such products as peas, cut beans, berries, peaches, certain fruit juices, egg magma, and similar products which lend themselves to this method of handling.

William J. Finnegan in 1937 developed an effective apparatus for quick freezing canned fruit juices in concentric pipes in which the canned product is bathed in a very cold, secondary liquid refrigerant. In 1948, the Pacific Grape Products Company, Modesto, California, installed a freezer of their own design to freeze fruits and vegetables in cans immersed in alcohol at −25 F. The rotating drum gives effective conduction due to constant movement of contents within the can.

Also in 1937, A. J. Stone devised the "Jackstone" apparatus for quick freezing both loose and packaged foods while located between flat, refrigerated, heat-conductive plates projecting radially in pairs from a central revolving hub.

Dehydro-freezing, a partial removal of natural water prior to freezing, was found by University of California workers to improve the texture of most frozen fruits and vegetables. Birdseye had previously been granted a patent on this idea in 1943, while F. B. Doyle assigned his Freez-Vac patent (1943) to Ingersoll-Rand. The latter apparatus, employing the principle of flash evaporative cooling under high vacuum, utilizes the steam jet to freeze foods by the flash evaporation of their own water. Other methods also utilize the refrigeration produced by the evaporation of the contained moisture. This is employed in the high vacuum technique of the National Research Corporation process now used widely for concentrating fruit juices for freezing. (See Chap. 12, page 137.)

There can be little doubt that there will be a further very great development of the frozen food industry. Many different types of meats, poultry, seafoods, fruits, vegetables, and cooked dishes will be frozen in ever-increasing quantities. Speed, efficiency, and sanitation will be leading characteristics of the apparatus by which these products are frozen. No one machine or type of machine will be suitable for all products. The development of such improved apparatus offers an inspiring opportunity for refrigerating engineers.

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If you searched this chapter for something which was not found in it, please let the editors know.

2. FRUITS AND VEGETABLES

FROM the point of view of quick freezing, animal and plant tissues differ in several ways and therefore require different procedures both before and during actual quick freezing operations. The most important of these differences arises from the fact that while animal tissues are dead before they arrive at the quick freezing plant (oysters and clams are exceptions), vegetables and fruits are very much **alive** up to the moment the former are blanched and the latter are actually frozen. While vegetables and fruits have many characteristics in common, they also have several points of substantial difference. A clear understanding of these similarities and differences is fundamental to the successful quick freezing of both fruits and vegetables. These considerations may, for convenience, be roughly classified as "biological" and "commercial" in nature.

Biological Considerations

As a rule, leakage from plant tissue which has been frozen and thawed is greater than that from animal tissue similarly treated. Quick freezing is therefore essential to the production of frozen fruits and vegetables of the highest quality, although certain cold-pack fruits to which sugar has been added before freezing may be of good quality if frozen very slowly to permit the sugar to penetrate the fruit tissue before freezing is completed. The advantages of rapid freezing are graphically set forth in **Fig. 1** and **Table 1.**[1]

Catabolic enzyme reactions begin the moment fruits and vegetables are harvested and, unless effectively controlled, may damage the product progressively up to the time it is finally cooked or eaten. Constant precautions must therefore be taken to hold enzyme reactions in check throughout harvesting, transportation and processing of the raw material and during post-freezing storage and distribution. **Sugar** is added to most fruits before or during freezing and serves both to retard certain enzymic changes during storage and to firm the fruit tissue and thus to lessen leakage when the product is thawed for use. **Heat** is employed to inactivate enzymes in vegetables immediately before freezing.

Both fruits and vegetables should be harvested and quick frozen at optimum maturity. Fruits should be soft-ripe, and vegetables at a point of tender maturity.

Commercial Considerations

Some fruits and vegetables have many **varieties,** relatively few of which are suitable for quick freezing. Care must be exer-

Table 1. Size of Ice Crystals in Various Frozen Products with Different Methods of Freezing

Product	Method of freezing	Size of ice crystals, microns		
		Thickness	Width	Length
Asparagus	Contact with dry ice	6.1	18.2	29.2
Asparagus	Sugar immersion	9.1	12.8	29.7
Asparagus	On metal plate, 0 F	15.3	63.1	86.6
Asparagus	Multiplate freezer, −40 F	87.6	768.0	820.0
Asparagus	Air blast, 0 F	324.0	544.0	920.0
Rhubarb	Contact with dry ice	10.0	31.0	85.0
Rhubarb	Sugar immersion, 0 F	9.0	39.0	72.0
Rhubarb	Multiplate freezer, −40 F	24.0	86.0	120.0
String beans, blanched	Sugar immersion	9.0	23.0	26.0
String beans, cooked	Sugar immersion	4.8	12.8	13.0

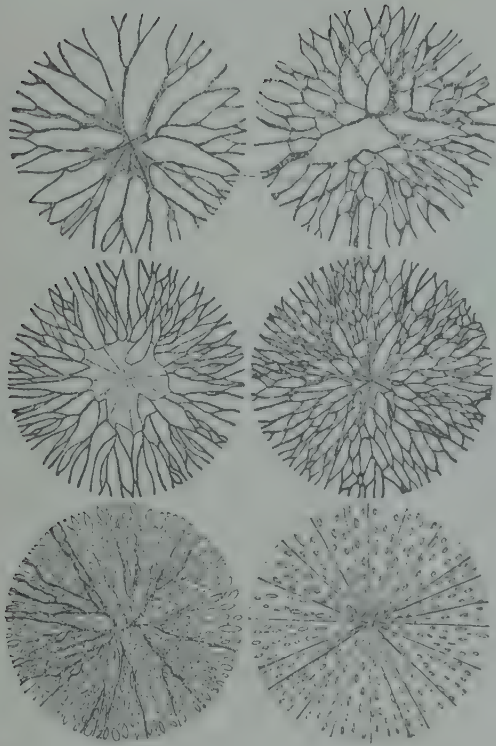

Fig. 1. Ice Crystal Patterns Produced in Carrots Frozen by Six Methods, Magnified 50 Times.[3]

Upper left: Air blast method, −28 F
Upper right: Air blast method, 0 F
Center left: Metal plate at 0 F
Center right: Double contact in package, −40 F
Lower left: Immersion, 0 F
Lower right: Direct contact with solid carbon dioxide.

cised in selecting those varieties which not only freeze well, but which can be grown economically in the immediate vicinity of the plant. Varieties should be selected which can, with a minimum of waste and labor, be dressed for freezing. Varieties should be chosen for their eye appeal as well as for their flavor. Mild-flavored varieties of such vegetables as spinach, cauliflower, and Brussels sprouts are usually considered best for freezing, as are the sweetest and most flavorful varieties of peas, lima beans, sweet corn and green and wax beans. Long production seasons for each product make for efficient plant operation. Good cold storage qualities are highly desirable in such fruits as apples and such vegetables as squash, certain varieties of which can be used to keep freezing plants busy during the winter months.

Vegetables

The vegetable freezing industry has grown very rapidly during the past decade. At present, the principal vegetables frozen are the following: peas, lima beans, green beans, spinach, sweet corn, broccoli, asparagus, cauliflower and Brussels sprouts. Frozen peas are more popular than any other vegetable and, consequently, are frozen in a greater quantity.

The process employed in preparing the vegetables for freezing depends, of course, entirely upon the product packed. In the case of peas, the vines are mowed in the fields, then transported to a vining station or freezing plant where they are vined (threshed). The vined peas are cleaned, washed, blanched (either in water near the boiling point, or in steam), then quickly cooled, quality graded by floating in brine, again washed, and finally inspected and packaged. The length of the blanching treatment given depends principally on the maximum size of the pieces of vegetable and upon whether the product is blanched in steam or boiling water.

An entirely different type of vegetable such as sweet corn obviously would be handled in a much different manner. The ears of sweet corn are picked in the fields and transported to the freezing plant. The first operation is husking. The husked ears are silked and then inspected, after which they may be blanched (preferably in a steam blancher) and then immediately cooled. The cool ears are sorted and the perfect ones of the proper maturity removed for packing as corn-on-the-cob. The over-mature and imperfect ears are passed through cutters. The bits of cob are removed from the kernels by mechanical means, then the whole kernel corn is packaged for freezing. In some plants where the corn is cut from the cob prior to blanching, a much shorter blanch is used. Details indicating the length of the blanching treatment are presented in Table 1, Chapter 7, of this Section (see p. 78).

Vegetables are frozen by the various methods described for the freezing of fruits. In addition, large quantities are frozen before packaging on either moving belts or on trays placed in an air-blast freezing tunnel. After freezing in this way,

the masses of frozen vegetables are broken up and the product packaged in any style or size of container desired.

Fruits

Commercial freezing of fruits in large containers has been an important industry for more than thirty years. Strawberries, cherries, and other small fruits have been frozen for the baking, flavoring, soda fountain, ice cream and preserving trade in large quantities for many years. More recently apples, apricots, fresh prunes, plums and various fruit purees are being packed in large containers. In the early years of this trade, the fruit was packed principally in 450-lb barrels, but more recently the 20, 30, and 50-lb slip cover enamel-lined tin cans have been more popular.

Usually, the above products are packed with sugar in ratios from one part sugar to two parts fruit to one part sugar to five parts fruit. They are frozen in cold rooms varying in temperature from −10 F to 0 F. The rooms are usually equipped with large fans blowing directly on the goods or other positive air circulating systems. For data on methods of packing fruits, see Table 3, Chapter 7, of this Section.

Packages must afford fruits and vegetables the maximum protection against exposure to air, loss of moisture vapor and fluctuations of temperature during storage and distribution. All packages should be filled as compactly and completely as possible, at the same time providing room for the expansion which takes place during freezing. Fruits receive maximum protection when the packages are substantially filled with sugar syrup, which may be provided either by the combination of dry sugar and juice extracted from the fruit by osmosis or by adding prepared syrup to the product before or after freezing. Fruit packages should be water-tight to prevent leakage of juice and syrup when the product thaws. Vegetable packages must be substantially moisture-vapor-proof but, as a rule, need not be water-tight. Rectangular packages are, for obvious reasons, highly desirable for substantially all quick frozen products. Shipping containers should be composed of corrugated fiberboard or other material having a comparable heat-insulating value, for such containers offer a substantial measure of protection to the product against highly deleterious temperature fluctuations (**Fig. 2**).

Packaging and Freezing

The quick frozen packs which are prepared for the retail and institutional users are packaged in smaller containers, usually waxed cardboard cartons. The container usually has an overwrap of printed cellophane or waxed paper and a protective liner. For fruits in syrup, a heat-sealable bag of coated parchment is usual. For dry products, the liner may be a loose or attached sheet of moisture-vapor proof cellophane or a tightly glued inner surface of waxed, wet-strength paper. Single-piece, metal-end cartons of wax-impregnated board or wax-sprayed after fabrication are meeting broad acceptance. An all-metal rectangular can is also becoming popular. The accompanying table (**Table 2**) indicates the sizes of containers usually used for packing retail and institutional size frozen fruits and vegetables. For the quick-freezing of fruits, numerous methods are used. For freezing in the packages, it is desirable to use conduction methods by freezing in direct contact with heat-conducting metal surfaces. However, high

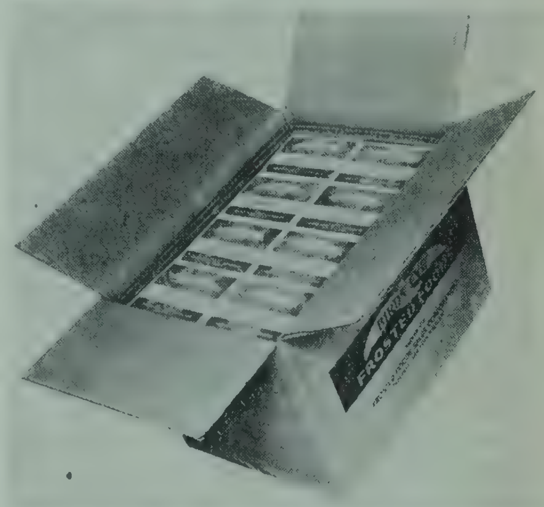

Fig. 2. Lined Corrugated Fiberboard Container Used for Storage and Shipment of Frozen Fruits and Vegetables.

Table 2. Sizes of Packages Used for Retail and Institutional Frozen Food Packs

Container Capacity Product	Maximum and Minimum Dimensions						Commonly
	Length		Width		Depth		Used Size
	Max.	Min.	Max.	Min.	Max.	Min.	
							Average
10 oz veg.	$5\frac{1}{4}''$	$5''$	$4\frac{1}{4}''$	$4''$	$1\frac{3}{4}''$	$1\frac{1}{8}''$	$5\frac{1}{4} \times 4 \times 1\frac{1}{2}$
12 oz veg.	$6\frac{1}{8}''$	$5''$	$4\frac{1}{8}''$	$4''$	$1\frac{7}{8}''$	$1\frac{3}{8}''$	$5\frac{3}{8} \times 4 \times 1\frac{3}{4}$
16 oz fruit	$5\frac{1}{2}''$	$4\frac{7}{8}''$	$4\frac{1}{2}''$	$3''$	$2''$	$1\frac{1}{2}''$	$5\frac{1}{4} \times 4 \times 1\frac{1}{3}$
							Average
$2\frac{1}{2}$ lb veg.	$10''$	$9\frac{3}{8}''$	$6\frac{1}{4}''$	$5''$	$2\frac{3}{4}''$	$1\frac{3}{4}''$	$10 \times 5\frac{1}{4} \times 2\frac{1}{2}$
5 lb veg.	$9\frac{5}{8}''$	$9\frac{5}{8}''$	$8''$	$8''$	$2\frac{3}{4}''$	$2\frac{5}{16}''$	$9\frac{5}{8} \times 8 \times 2\frac{3}{4}$
10 lb fruits	$12\frac{1}{4}''$	$12\frac{1}{4}''$	$8''$	$8''$	$2\frac{3}{4}''$	$2\frac{3}{4}''$	$12\frac{1}{4} \times 8 \times 2\frac{3}{4}$

velocity air-blast freezing has proven very practical and is now widely used. According to the latter procedure, the packaged products are usually placed on trays which are put on mobile racks and then wheeled into the air blast chamber. Loose-frozen products such as peas and lima beans are packaged after freezing but require larger packages as noted in Table 2.

Storage of frozen fruits and vegetables is a very critical operation and can be successful only if several well-known rules are meticulously observed. The lower the storage temperature, the better the product will keep. One of the largest and most successful distributors of quick frozen fruits and vegetables requires that a **temperature** of -5 F be maintained. Storage temperatures must be as nearly constant as possible, for each time temperatures are raised, some of the ice crystals in the product are thawed, and when the temperatures are again reduced, this moisture freezes onto existing ice crystals so as to increase their size. Holding of the product in proper cold storage is equally essential. If the storage room has warm walls, floor or ceiling, free circulation of air on all sides of every stack of stored frozen foods is necessary.

Proper **transportation** temperatures are also necessary with quick frozen foods, for if such products are allowed to become warm and are then slowly recooled to proper storage temperatures, they may be damaged. Therefore temperatures in cars and trucks must be maintained as uniformly as possible, not in excess of $+5$ to $+10$ F. Stacks of product in transit, like those in storage, must be kept away from floors, ceilings, and walls.

Quality control of the most rigid sort is essential and has many phases. Perishable foods are not rendered sterile by freezing and storage at low temperatures, and it is therefore requisite that they be sanitarily handled at every stage of production, preparation, freezing, storage, distribution and final preparation for the table. Uniformity of quality in any given grade or brand is likewise important. Moreover, each quality of pack should be uniform throughout the season and from year to year, whether the pack is intended to be of medium, good, or top quality.

Speed is important in preparing fruits and vegetables for quick freezing. The product should at all times be kept as cool as practicable in order to minimize oxidation, microbiological growth, and enzymic activity. Inspection must be ample and constant. One discolored lima bean or one grain of sand can render a whole package of product unsatisfactory. Frequent sampling of the product, both before and after freezing, is essential to a uniformly good pack, and these examinations should be both organoleptic and microbiological. Such control operations as the above require proper laboratory facilities and trained personnel.

Enzymes may be easily inactivated in vegetables by the use of hot water or steam. Because the preparation of frozen vegetables for the table usually includes cooking, it is therefore not detrimental

to have the product become limp when thawed. In the earlier days of quick freezing, water was commonly used for enzyme inactivation. More recently, however, live **steam** has come into extensive use, for it leaches from the product a smaller percentage of the vitamin and mineral contents. Batch-blanching in steam under pressure has been used to a limited extent, and continuous steam pressure blanchers are now being developed (Table 2, Chapter 7, p. 79).

The enzymes of fruits for freezing (apples are an exception) are not usually inactivated by heat, for heating changes the appearance, texture and flavor of the fresh product. Therefore sugar **syrup** is commonly used to protect frozen fruits from oxidation and thereby retards many of the undesirable changes which the fruit enzymes would otherwise bring about during storage. Sometimes the syrup is generated by adding dry sugar to the fruit and allowing it to extract water from the product by osmosis before and during freezing. In other cases a heavy syrup is prepared and poured over the fruit after it has been packaged for freezing (**Table 3**).

Many frozen fruit **juices** are delicious, but in their preparation certain precautions must be used in order to maintain high quality. Oxidation must be prevented, and the plant should be kept clean. Juice must be extracted only from clean, ripe fruit. The juice must be kept under constant refrigeration, and as much oxygen as practicable must be evacuated from the juice before it is packed in containers for freezing. Recently the concentration of evacuated orange and other fruit juices has become a major industrial operation, producing in vacuum cans naturally flavored juices at retail prices competitive with the fresh fruit. (See Chap. 12.)

For detailed procedures to be followed in preparing individual fruits and vegetables for freezing preservation, various books are available.[2]

There is every reason to believe that the quantity of fruits and vegetables preserved by freezing will continue to increase. But everyone connected with the frozen food industry must remember that freezing is only one of many excellent ways to preserve perishable foods and that the success of the industry depends on establishing and maintaining the highest possible standards of quality. Constant improvement must take place in the quality of raw material, in pre-freezing operations, sanitation, packaging, freezing, storing, shipping, merchandising, and preparation for the table. No one of these steps may be slighted, for if any step is neglected, the product will be of less-than-optimum quality at the time it is eaten—and that is the time when the consumer will judge its quality.

Table 3. Effect of Viscosity and Velocity of Liquid Media on Freezing Rate

Solution	Viscosity, centipoise	Velocity, in. per sec	Time, min
72.5% syrup	1500	0	14.0
72.5% syrup	1500	.6	7.7
72.5% syrup	1500	6.0	5.5
72.5% syrup	1500	12.0	3.0
58% syrup	725	0	12.0
58% syrup	725	2	5.0
58% syrup	725	4	2.5
22% brine	10	0	5.5
22% brine	10	2	3.7
22% brine	10	4	2.4

Bibliography

1. Figures and tables in this chapter are from the 1940 edition of the Refrigeration Applications volume *Refrigerating Data Book*, as included in the material prepared by J. G. Woodroof.
2. Tressler, D. K. and Evers, C. F., The Freezing Preservation of Foods, Avi Publishing Co., New York, N. Y.
3. Woodroof, J. G., *Refrigerating Engineering*, vol. 37, p. 9, Jan. 1939.

If you searched this chapter for something which was not found in it, please let the editors know.

3. FISH REFRIGERATION

FISH may be divided into two broad groups according to the flesh composition. The first group includes fish which store oil or fat in their livers and for this reason are generally referred to as the non-oily varieties, such as cod, haddock, and pollock. The other group contains those fish which store their oil in the muscle tissue throughout the body and are termed the oily or fatty species. Some of the well-known representatives of this group are salmon, mackerel, and herring. The percentage composition of the oil in the flesh varies considerably within these two classifications. The flesh of the non-oily fish, in general, contains less than 3 per cent fat, while those placed in the oily class contain more. Shellfish would be placed in the non-oily group if classified according to fat content. This classification of fish is suggested since the type of spoilage in cold storage is, within certain limits, dependent upon the degree of fatness (Table 1).

There are three primary types of spoilage responsible for deterioration: (1) the action of bacteria which contaminate the seafood through handling after removal from the water; (2) the oxidation of the oil or fat in the flesh; and (3) the action of enzymes contained within the tissue.

James M. Lemon, Author Chapter 3. Born 1891 in Anxvasse, Mo. Educated at Missouri Westminster College, 1913, and Univ. of Florida, BS, MS, 1925. Formerly connected with the Great Western Sugar Co. 1913–17; Chief Chem., U. S. Army, 1917–18. Industrial Sugar Co., 1919–20; Asst. Chem. Florida, 1922–25; Assoc. Res. Chem., Complex Ores Corp., 1926; Asst. Chem. Bur. Internal Revenue, 1926–28; U. S. Fish and Wildlife Service, Assoc. Chem., 1928–43; Chief Technologist, 1943; Dir. Res. Technological Laboratory, Gloucester, Mass., 1930–35; College Park, Md. 1935–43.

Co-author of the 2nd ed. of "Marine Products of Commerce," Reinhold Publ. Co., N.Y. (in preparation); contributed to numerous government bulletins and journal articles on the chemistry and technology of fishery products with special reference to smoking, freezing and quality control. Member of Institute of Food Technologists; Amer. Chemical Society (Dir. N.E. Sect. 1935); National Fisheries Inst.; Sigma Xi. At present he is Chief Technologist, U. S. Fish and Wildlife Service, Washington, D.C.

When fish are frozen and stored at a low temperature, the action of the bacteria is almost entirely arrested, and, for all practical considerations, this type of spoilage is eliminated so long as the fish are held in a frozen condition. There are some types of bacteria which are able to resist extremely low temperatures by remaining in a state of hibernation. These types may cause considerable damage through spoilage if the temperature of the storage room is for any reason raised to a point favorable for growth, or if defrosting occurs during transit from one point to another.

The oxidation of the oil or fat is another source of spoilage of frozen fish, even in cold storage rooms at low temperature. Oxidation is indicated by yellow discoloration appearing on the surface of the skin or on the flesh at points where it is exposed to the oxygen of the atmosphere in the warehouse. Low temperatures usually employed in the storage of fish retard but do not entirely prevent the chemical combination of oxygen and the oil or fat of the fish. If the fish are stored over long periods of time, the development of rancidity in the oil or fat is more likely to occur than when the storage period is only of short duration. When the fish are properly glazed with a thin coating of ice, or are covered with one of the several available moisture-proof wrappings, this reaction between the oxygen of the air and oil or fat of the fish is greatly retarded. However, the losses through oxidation or rancidity will be held at a minimum if the fish are carefully reglazed when it is noticed that the coating of ice has become thin due to evaporation, and if the fish are not held in storage over periods of excessive length.

The enzymes responsible for the third type of spoilage are substances contained in the flesh of the fish which build up and tear down the tissues during the life processes. These reactions are common to all forms of animal life and are automatically controlled so long as the animal is alive.

Upon death, the enzymes which act as builders of tissue during life are inhibited, and only those which **tear down the tissue** remain active. The temperature at which the tissue is stored has a definite effect upon the rate or speed of the digestive reaction due to these enzymes. According to a well-known physico-chemical law, the rate of this reaction is doubled for each 18 F increase in the temperature of the tissue. Thus, in fish stored at 32 F the rate of the reaction is reduced by one half compared to those stored at a temperature of 50 F. And at a temperature of 14 F, the rate of the reaction is theoretically only one-fourth that of 50 F. While the reaction is retarded by storing food substances at low temperatures, it is not possible to lower them sufficiently to stop it entirely. It is not economically feasible to make use of excessively low temperatures, and the effect of them on food products may in itself cause damaging results. It has been found that −10 F is usually low enough to store fishery products so that minimum deterioration and maximum storage life may be obtained.

While the action of the enzymes will eventually cause complete spoilage of any animal tissue as a food, they cannot be considered entirely detrimental, since the process of **ripening** is necessary for meats derived from warm-blooded animals. The ripening process is the result of enzymatic action and is not necessary or desirable for fishery products, since the texture and composition of the flesh are such that a change in texture is undesirable and the flavor is available without it.

Chemical Composition of Seafoods

The accompanying tables set forth the composition of the most common varieties of seafood. The first column of Table 1 contains the percentages of dry substance of the various species; the moisture content can be derived by deducting the amount shown in this column from 100 per cent. It has been stated that fish could be divided into two groups, fatty and non-fatty; those in which oil or fat content is above 3 per cent are generally considered in the former class while those having less compose the non-fatty. The third column

Table 1. Chemical Composition of Common Varieties of Food Fish

Species	Total solids, %	Fat, %	Protein, %	Ash, %	Calories per lb
Abalone	26.0	0.5	21.7	1.4	460
Albacore	33.8	7.6	25.3	1.3	770
Alewife	25.6	4.9	19.4	1.5	550
Barracuda (California)	25.0	3.1	21.2	1.3	510
Bass (Atlantic sea black)	20.7	1.2	19.2	1.2	395
Bass (California white sea)	23.7	0.5	21.4	1.4	410
Bass (striped)	22.3	2.7	18.9	1.2	455
Bluefish	25.4	4.0	20.5	1.2	535
Bonito (Atlantic & Pacific striped)	32.4	7.3	24.0	1.4	735
Butterfish	28.6	10.2	18.1	1.4	745
Carp	22.1	2.2	18.2	1.2	420
Carp (river)	23.8	3.2	19.2	1.2	480
Clams	19.4	1.7	13.6	2.0	355
Cod	17.4	0.4	16.5	1.2	315
Crabs (Atlantic & Pacific)	20.0	1.6	16.1	1.7	370
Croaker	22.6	2.2	17.8	1.3	415
Drum (red)	19.8	0.4	18.0	1.3	345
Eels	28.4	9.1	18.6	1.0	710
Flounder	17.3	0.5	14.9	1.3	290
Grayfish	27.7	9.0	17.6	1.0	685
Grouper (spotted)	22.5	1.2	19.1	1.3	395
Haddock	18.3	0.3	17.2	1.2	325
Hake	18.4	1.1	16.3	1.1	340
Halibut	24.6	5.2	18.6	1.0	550
Herring (Atlantic)	27.0	6.7	19.0	1.6	620
Herring (lake or cisco)	26.0	6.8	18.5	1.1	615
Herring (Pacific)	20.4	2.6	16.6	1.3	405
Horse mackerel (Pacific)	28.6	5.6	21.6	1.2	620
Kingfish (Pacific)	20.3	0.8	18.0	1.3	360
King whiting	22.7	3.0	18.3	1.3	455
Lake trout	29.2	10.3	17.8	1.2	745
Lobster	20.8	1.9	16.2	2.2	380
Mackerel (Atlantic)	31.9	12.0	18.7	1.2	830
Mackerel (Pacific)	30.6	7.6	22.2	1.4	715
Mackerel (Spanish)	33.9	13.3	19.8	1.3	900
Mullet	24.9	4.4	19.3	1.2	530
Mussels	22.9	2.3	14.4	1.6	435
Oysters	19.7	2.0	9.8	2.0	365
Perch (white)	24.3	4.0	19.3	1.2	515
Perch (yellow)	20.7	0.8	18.7	1.2	370
Pike (common)	20.2	0.6	18.7	1.0	365
Pilchard	29.2	8.6	19.3	1.2	700
Pollock	24.0	0.8	21.6	1.5	435
Pompano	27.2	7.5	18.8	1.0	665
Porgy	23.8	0.9	21.4	1.5	425

Table 1—Continued

Species	Total solids, %	Fat, %	Protein, %	Ash, %	Calories per lb
Red snapper	21.6	0.9	19.8	1.3	395
Salmon (Atlantic)	36.4	13.4	22.5	1.4	955
Salmon (king)	36.6	16.5	17.4	1.0	990
Scallops	19.7	0.1	14.8	1.4	335
Shad	20.8	3.8	20.9	1.5	535

Source: Fisheries Document No. 1000.

contains the protein value of the whole fish. **Protein** is the substance found in all animal tissue and composes a large portion of the muscle. It will be noted that the protein variation in the percentage composition of the fish is considerably less than any of the other components excepting the ash.

The ash or inorganic matter of fish flesh contains minerals necessary in every well balanced diet. Fish are particularly valuable in the diet since they contain large proportions of inorganic salts necessary for proper growth and development and are an excellent source of the necessary element iodine. The analysis of the ash of some of the sea-foods as expressed in **Table 2** indicates that these compare very favorably with some of the other common foods.

Where fish are received at the warehouse in an unfrozen condition and are to be frozen and stored, it is necessary to judge the **quality** of the fish before placing them in the freezer. This serves not only as protection to the warehouse operator, but also indicates to the shipper who has forwarded the fish, the condition of the shipment when received for freezing. When he has received this report, the shipper can then judge the length of time he can expect these fish to remain in good condition after they have been frozen and stored.

Table 4 outlines the distinction between fresh and stale fish but leaves considerable latitude to human judgment. More scientific methods for judging the condition of fish are at the present time in use in various laboratories. Not any of these is suitable for use except in a laboratory.

Filleting of Fish

The term fillet is applied to a slice of fish, taken the length of one side of the body; thus, each fish furnishes two fillets. The fillets are usually cut so that they contain no bones or only a very few. The skin is generally removed, though a few dealers prefer to leave it on since without the skin it is practically impossible to identify the species of fish from which the fillet was prepared. Filleting has the advantage of concentrating all waste in one point so that it can be utilized for meal and thus is not a total loss. The purchaser has all edible meat without the bother of dressing; there

Table 2. Mineral Content of Fillets of Fish and Comparable Foods

Species	Dry Matter	Calcium	Magnesium	Phosphorus	Iron	Copper	Iodine
	Percentage by weight of the fresh edible portion						
Cod	17.7	0.0110	0.0280	0.1859	0.000518	0.000041	0.000103
Flounder	21.3	.0117	.0305	.2053			.000029
Haddock	18.7	.0165	.0236	.1731	.000516	.000041	.000513
Lake herring	17.9	.0116	.0172	.1518			
Mackerel	19.9	.0048	.0281	.2169	.001224	.000115	.000053
Mullet	23.9	.0261	.0318	.2198	.001779	.000082	.000485
Pilchard	20.5	.0422	.0237	.2115	.002483	.000166	.000013
Red snapper	21.7	.0162	.0276	.2279	.001158	.000038	.000031
Beef	36.9	0.012	0.024	0.216	0.0030	0.00010	0.000001
Milk	12.7	.120	.012	.093	.0002	.00002	.000007
Potatoes	26.6	.014	.028	.045	.0009	.00017	.000004
Tomatoes	5.7	.011	.010	.026	.0006	.00007	.000004
White bread	59.3	.027	.023	.093	.0009	.00034	.000006

Source: Bureau of Fisheries Investigational Report 41.

is no waste such as heads, backbones and entrails. The most common species of fish utilized in the filleting industry are haddock, small cod, flounder and whiting, pollock and rosefish. Usually those fish weighing 4 lb or less are cut as fillets, since the object of the fillet is to prepare a cut suitable for cooking, and the larger fish are usually too thick to fry without further cutting.

After the fillets are cut from the sides of the fish, they are **brined** in a solution containing approximately 3 lb of salt to each 12 gal of water; frequently, the solution is chlorinated so that the surface bacteria are killed. The strength of the chlorine should be about five parts per million or strong enough to give a distinct odor of chlorine.

Water for use in preparing a brine and chlorination bath for washing fillets prior to freezing should be taken from the most sanitary supply available. It is preferable to make use of the city water supply, which in most cases is chlorinated and is suitable for drinking purposes. The water should be placed in the brine tank and sufficient chlorine added to give a concentration of approximately three to five parts per million. There are various test papers which can be purchased which will indicate the concentration of chlorine in solution. This constitutes a simple and sufficiently accurate test for control and can be manipulated by one who is not scientifically trained. The maintenance of the concentration of chlorine is important if the bath is to be effective. There should be sufficient salt added to give a salinometer reading of 25 to 35 degrees. The preparation of this strength brine can be made by referring to the attached **Table 3** showing the salinometer readings for brine of different strengths,

Table 3. Salinometer Values for Mixtures of Salt and Water

Salinometer reading	Salt, lb	Water, lb	Salinometer reading	Salt, lb	Water, lb
100	26.3	73.7	50	13.3	86.7
90	23.7	76.3	40	10.7	89.3
80	21.1	78.9	30	8.1	91.9
70	18.5	81.5	20	5.5	94.5
60	15.9	84.1	10	2.6	97.4

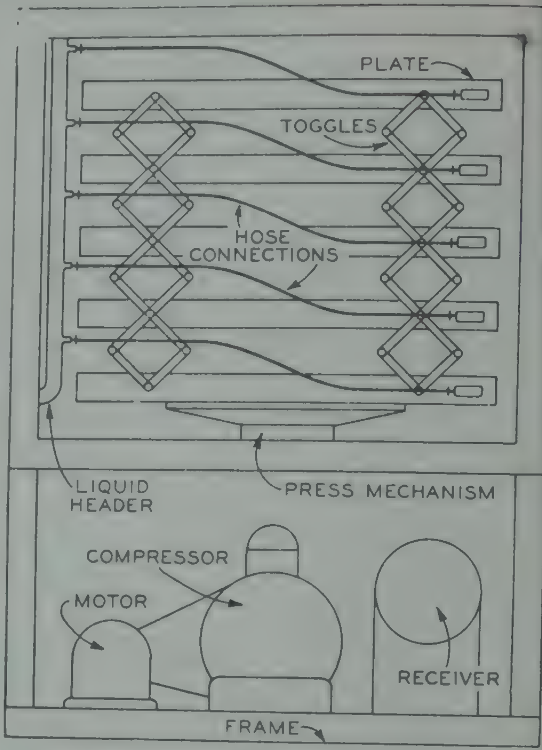

Fig. 1. Section of Accordion Plate Freezing System.

the weight of water being considered as 8 lb per gal.

If the fish plant does not have access to the equipment for preparing chlorine solutions from steel cylinders of liquid chlorine, it is possible to use chemicals. There are several compounds of chlorine known as **hypochlorites** available at chemical supply and wholesale drug houses. These compounds are in a powdered form, and directions for making up solutions with water to yield definite quantities of free chlorine are carried on the labels. From some of these, concentrated solutions of chlorine can be prepared which can be diluted with water to make the strength desired for the brine bath.

If possible, the brine tank should be fitted with cooling coils of sufficient capacity to hold the temperature of the brine at 35 to 45 F. In a number of installations the brine tank is fitted with a belt conveyor which carries the fish through the brine at such a slow speed that it is thoroughly chilled when it reaches the wrapping table. If the capacity of the plant is not sufficiently large to make such an installation

PREFACE

This volume is one of a continuous series of books published by the Society since 1932. The sub-title "Refrigeration Applications" was adopted with the 1940 edition. The contents are intended to cover the use of refrigeration and refrigeration machinery. Refrigerating engineering divides into two broad major fields which for want of better designation can be termed "Application Engineering" and "Design Engineering." The line of demarcation between these two fields is not sharp and definite. Like the sciences of physics and chemistry, it is sometimes difficult to tell where one stops and the other begins. They are interrelated and overlap.

As near as their field of activities can be defined, *design engineering* deals with the development of products, such as condensing units, evaporators, valves, controls, refrigerator cabinets, assemblies, etc., carrying them through from the conception of the idea, necessary research for development, choice of materials for construction, physical characteristics of the product, such as dimensions, etc., tooling for production and the actual production of the product until it is turned over to the manufacturer's sales department to be sold to the user.

Application engineering may be considered as dealing with the sale and use of the product. This activity starts with the time it is turned over to the sales department and continues until it is actually in use and successfully solving the refrigeration problems of the user. It deals with sales technique, food technology and other technical knowledge necessary to apply the product to the user's needs, and to install and maintain it after it is in the user's hands.

The early "Refrigerating Data Books" published by the Society, covered both of these fields. However, the greatly increased uses of refrigeration, not only in connection with preservation of foods, but in many industrial processes and air conditioning, made it increasingly difficult to cover both fields in one volume. Consequently, starting with the 1940 edition, it was decided to publish two data books on alternate years, dividing the material contained in these books into these two broad general classifications.

The 1949 Refrigeration Data Book—Basic Volume—was intended to cover primarily the field of design engineering, including the science and art of refrigeration proper, refrigeration cycles, kinds of machinery and equipment used to extract or exchange heat, etc. This 1950 Refrigeration Applications volume covers the use of the science and art of refrigeration and the application of refrigerating machinery and associated equipment to solve the user's needs.

Certain fundamental information such as conversion tables, refrigerant characteristics, refrigeration glossary, etc., are not included in this volume. Reference to the Basic Volume for such data will be necessary.

The subject matter of this volume has been influenced by technological developments during the war and since the war, especially more uses of low temperature refrigeration, frozen foods, and increased uses of refrigeration for industrial applications. Emphasis has been placed upon food technology in many chapters in this volume. A large portion of refrigeration machinery and accessories produced is used for the preservation of food. Application of refrigeration machinery to food processing, handling and distribution cannot be successful unless the appli-

cation engineer has some knowledge of the characteristics of the products with which he deals. The same is true of industrial applications. Knowledge of the process and products involved are also required by the application engineer for intelligent and successful application of refrigerating equipment to that field. Air conditioning has been discussed as a growing business for the past decade or more. Recently, it has been increasingly coming into its own, and many manufacturers are optimistic regarding its future.

The editorial procedure used in this volume follows that initiated by Dr. Donald K. Tressler in preparing the 1946 volume. The book is divided into eight major sections, each handled by an associate editor who is a specialist in the overall field covered by his section. In each section, chapter authors have been selected who are well informed and experienced in the particular field covered by the chapter.

A certain amount of overlapping of the material in the various chapters will be noted. The editorial staff has considered this an advantage, rather than a disadvantage. It provides a more complete treatment of the subjects covered by each chapter, and partially eliminates the necessity for reference to other chapters in the book, thus saving time for those who use the book. Bibliography is included with most of the chapters to assist those who are interested in searching further for more detailed information.

This volume contains 81 chapters. A complete rewrite of the 1946 volume was considered unnecessary, as there were not sufficient new advances in many fields of refrigeration application to justify such procedure. Five new chapters (11, 12, 33, 45 and 48) have been added covering new developments or subjects which have increased in interest or in importance since the 1946 edition. Some chapters in the book have been entirely rewritten and the remainder have been carefully checked and edited. A few have been reprinted exactly as they appeared in the 1946 edition. Others have been appropriately changed, based on new knowledge and improvements in the art. When controversy exists in connection with subject matter, authors have been instructed to present both sides impartially, permitting the user of this volume to adopt the solution appearing best suited to his needs until the controversy is resolved.

Attention is also invited to the Refrigeration Classified Section. This includes sources of materials or components which through manufacturing, assembling or field installation, may become integral parts of various types of refrigeration or air conditioning devices or systems. Complete package units, such as household refrigerators, unit air conditioners, or commercial refrigeration fixtures are also included. No effort has been spared to insure accuracy and completeness in this section. It is included as a service to readers of the book to enable them to find sources of supply for various items which are essential to the proper application of refrigerating equipment.

Some early editions of the Refrigerating Data Book contained information relative to the economics of the refrigeration business, such as data on dollar income and unit output of various parts of the refrigerating machinery industry or associate industries. This has been eliminated, as it has no bearing on the field of application engineering, being a part of the field of market research. Current information can be obtained from the Bureau of Census. Comparative statistics can then be built by reviewing an article "The Demand for Refrigeration" published in *Refrigerating Engineering* November, 1943, page 321.

Suggestions by readers as to omissions, subject matter requiring clarification

or inconsistencies in the text will be welcomed by the Society. Such suggestions will be most helpful in compiling more useful and better future editions.

The authorship of the various chapters is indicated on the section contents inserts at the beginning of each section. A new feature has been added in the short biographical sketch given for each associate editor and author.

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This volume was indexed by Mr. Gerald A. Fitzgerald, Associate Editor of Section I. Refrigeration applications involve many items of food technology as well as refrigeration. Mr. Fitzgerald's wide acquaintance with both of these fields has resulted in an improved and more usable index.

Acknowledgment is also made to the following editorial participants acting for the staff of the publisher—Charles E. Oberst, Edith Challandes, and Julia Menzel. The help of the secretaries and stenographers of the editors and chapter authors in typing material and handling other details in the preparation of the manuscripts is also acknowledged and deeply appreciated by the Society.

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This volume represents the unselfish efforts of a large number of individuals who merit the thanks of the Society and the refrigeration industry for the generous contribution of their time, experience and ability which has made this book possible.

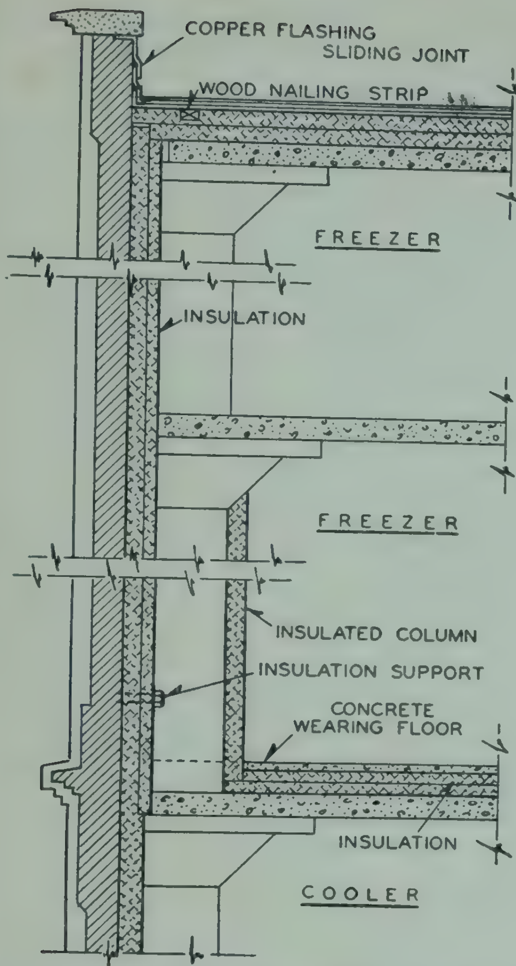

Fig. 2. Insulation of Typical Freezer Storage in Cold Storage Building Using Curtain Wall.

economical, ice and salt can be added from time to time to hold the temperature at the desired point. The fillets can be placed in wire baskets or trays and immersed in the brine until they are cool. This precooling is important since it shortens the time for quick freezing the fillets.

If the temperature of the brine tank is permitted to rise and the concentration of chlorine is not maintained, the fillets may be contaminated by being dipped. Both the chlorine and the cold brine reduce the growth of bacteria if the concentration and temperature are maintained as suggested. It is further suggested that the brine be dumped when it has become discolored with blood and diluted with slime, and fresh brine be prepared. The frequency of dumping will depend upon the quantity of fillets passing through it.

The fillets are removed from the bath and, in many instances, wrapped in some type of moisture-proof wrapper and packed into paper cartons, tin or wooden boxes of sizes varying from 5 to 30 lb. In general, those fillets which are to be shipped to the market and sold unfrozen are packed in tin boxes or fibre cartons fitted with a tight cover. These boxes are then packed in large wooden boxes and covered with crushed ice.

Those which are to be frozen are packed in paper cartons and sent to the freezer where they are frozen in the carton. There should be as little delay as possible in sending the packed cartons to the freezer for freezing, since delays permit the fillets to become warm, and the advantage gained by chilling in brine is lost. In many operations the cartons are wrapped in some type of moisture-vapor-proof material and hermetically sealed by one of the many methods in use for this purpose. These cartons are, in turn, packed in large single corrugated paper cartons lined with additional corrugated board or in cartons of double-

Table 4. Criteria of Quality in Fish

Strictly fresh fish	Stale fish
1. Odor of fish, fishy.	1. Odor stale, sour or putrid.
2. Eyes bright, not wrinkled or sunken.	2. Eyes dull, wrinkled, sunken.
3. Gills bright red, covered with clear slime; odor under gill covers fresh, fishy.	3. Gills dull brown or gray, slime cloudy; odor under gill covers sour and offensive.
4. Colors bright.	4. Colors faded.
5. Flesh firm; in quite fresh fish the body is stiff; impressions made by fingers do not remain; slime present and clear (eels, halibut).	5. Flesh soft and flabby; impressions made by fingers remain; slime absent (halibut), slime cloudy, ropy (eels).
6. Belly walls intact.	6. Belly walls often ruptured, viscera protruding.
7. Muscle tissue white.	7. Muscle tissue becomes pinkish, especially around backbone.
8. The vent is pink, not protruding.	8. The vent is brown, protruding.

Source: Refrigeration of Fish, by Harden F. Taylor, Bureau of Fisheries, Document No. 1016.

walled construction, and sealed for storage or shipment.

Occasionally fish fillets are packed in the 10 and 20-lb containers and frozen in a solid block. It would be advisable to revise this method to include a piece of parchment, waxed paper or cellophane between each layer of fish. Unless this is done it is difficult to separate the fillets without complete defrosting, and, unless the entire package is to be used at once, considerable deterioration of the package may result. If attempts are made to remove the fillets without defrosting they are likely to be badly torn, since without separators of some type they adhere tightly to each other. A piece of material between each layer in the box would make it possible to remove the fillets one at a time while still frozen.

In many instances, the larger size fish represented by halibut, some species of salmon, swordfish, and large red snapper and cod are prepared for the market as **steaks.** The fish steak is prepared by slicing the fish crosswise at intervals of approximately ½ in.; each steak of all except swordfish usually contains one joint of the backbone as well as some of the smaller bones. These steaks are often cut by means of a band saw after the fish have been frozen. The cuts are washed and wrapped in a manner very similar to the fillet and packed in various size packages either for storage or immediate sale.

Freezing Fish at Sea

In general there is a period of several days to two weeks or more lag between the capture of fish at sea and the landing of them at the processors establishment. And even though they are packed in crushed ice as soon as possible after capture, there is considerable deterioration before they enter marketing channels. The industry, for several years, has studied methods for overcoming this lag period without arriving at an entirely satisfactory solution.

Freezing fish at sea is not new. It has been practiced by the Dahl process of spraying brine over fish packed in wooden boxes ready for market. Danish and Norwegian interests have attempted complete processing on factory ships. California Tuna vessels have extended their cruising area for some years by batch freezing in brine and storing dry in the refrigerated hold. During the past few years, several fishing vessels have been equipped with either blast or sharp freezers. Fillets have been cut from the fish immediately after catching, packaged and frozen on board the vessel. The flavor, appearance and texture of these fillets was far superior to those handled in the usual manner. These operations were not entirely successful, due to the difficulty of cutting fillets on the pitching and rolling vessel at sea. Filleting is now done entirely at shore plants.

More recently fish on these vessels have been frozen in the round in the freezers as rapidly as possible. They were then glazed, and stored in the hold at a temperature of 0 to −10 F and held until landed. After landing at the filleting plant, those which had been frozen in the round at sea, were defrosted only sufficiently for cutting fillets. As soon as the fillets were cut and packaged, they were refrozen for storage and future sale. This method of handling is a decided innovation since it has been an axiom that once frozen, fish could not be defrosted and then refrozen satisfactorily.

The fillets which have been prepared from the defrosted round fish frozen at sea have superior flavor, texture and a slightly smaller drip than those cut from the fish packed in ice for a week or more before filleting. These characteristics are further emphasized upon long storage. The probable explanation of this lies in the superior quality of the fish when originally frozen, and the degree of defrosting to which they are subjected before cutting the fillets.

Several trawlers which have operated in the Bering Sea and landed their catches in Seattle, are equipped to freeze the round fish at sea. Sufficient freezer capacity to handle from 2000 to 3000 pounds of round fish per hour should be provided to accomplish the necessary results. Since, during trawling operations, under good fishing conditions, this is about the rate at which the fish are landed on board. Refrigerated storage space in the hold of the vessel should be available for from 200,000 to 300,000 pounds of fish. The temperature of the storage hold should be 0 to −10 F

in order to insure retention of the highest quality in the fish.

Refreezing Packages Defrosted in Transit

There are occasional instances in which frozen packages of seafoods become partially or totally defrosted during transit or even while in storage. When this has occurred it is necessary to exercise considerable care in the handling, or the loss due to spoilage may be excessive. The first step in making an examination of such a shipment is a careful **inspection** of each package in each carton. The packages should be separated into two groups, those only partially defrosted and those which are completely defrosted. The first lot, the **partially defrosted** cartons, can be placed in a quick or sharp freezer and handled in the same manner as that which was used in the original freezing operation. After they are refrozen the individual packages can be repacked in the shipping carton for storage. If attempts are made to refreeze in the original shipping carton it is likely that excessive losses by spoilage will be experienced. This is explained by the fact that the carton is a fair insulator, and, should the packages be placed in it before they are solidly frozen, several days would probably be required for freezing those in the center of it. During this lapse of time spoilage could occur and then the packages in the center would be unfit for food.

In handling the second lot, or those which are **completely defrosted,** extreme care should be used in separating those which are in first class condition from those in which a slight off odor has developed. The former can be refrozen as described above, while the latter should be disposed of immediately. It is never advisable to refreeze fillets or other sea-foods which show signs of decomposition. This results not only in an unfavorable reaction toward the particular type of sea-food but to frozen fishery products in general, and the consumer may assume that all fish which have been frozen are of an inferior grade.

Freezing Methods

Fish are frozen by any one of the great variety of quick freezing installations in use at the present time. These are too numerous to treat individually and for this reason they may be classed into four groups: (1) sharp freezer, (2) air circulating freezer, (3) chilled metal contact freezer, and (4) brine spray freezer.

The first method of freezing to be adopted was the **sharp freezer** method. The fish to be frozen were placed in a room which was maintained at as low a temperature as possible and left there until frozen. This method depends upon conduction of the heat from the fish to the refrigeration coils by air convection. The process is generally considered a slow one, since air is a relatively poor conductor of heat. There are a number of methods for attaining a rapidly circulating **air system.** A few types of freezers use solid carbon dioxide as a refrigerant instead of the conventional brine coils.

Another class of freezers is that in which the fish are placed in contact with a chilled metal **plate.** In some, the plates are in contact with brine or direct expansion coils, while in others the plates are arranged so that one surface is in contact with brine while the other is in contact with the fish which are to be frozen. Still another variation of the plate system depends on the fish, usually packaged, being placed between two plates chilled by direct expansion ammonia coils or by brine sprayed on both the top and bottom plates.

The **brine spray** or fog systems, as the name indicates, force a fine spray of chilled brine into a cabinet in which the fish are frozen. In this type of freezer, the brine is

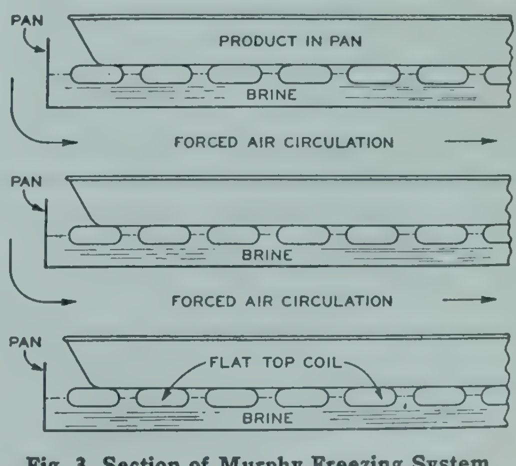

Fig. 3. Section of Murphy Freezing System.

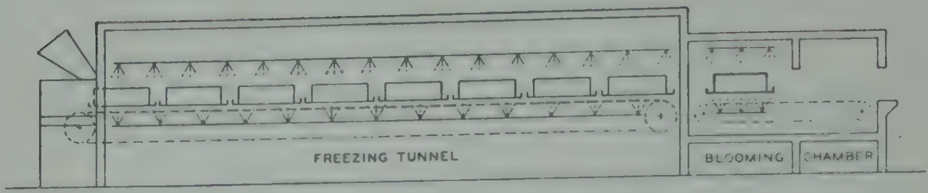

Fig. 4. Section of Typical Freezing Tunnel.

usually sprayed directly upon the surface of the fish, after which they are packaged when frozen. There are many variations in the method of arranging the spray nozzles and handling the fish to be frozen. Some of the freezers of this type are arranged so as to be continuous.

Shellfish and Crustaceans

All species of shellfish may be frozen by any one of the varieties of quick freezing methods which are in use. While there is no set general practice in the preparation and freezing of this seafood, the following suggestions will be of value. Only those in a prime condition of freshness should be selected for freezing and storage for future market. They may be frozen either in tin containers having a crimped-on top or in paper cartons which are impervious to evaporation of moisture. The loss of moisture from any of these species causes a discoloration. The size of the container is governed by the market for which it is being prepared. The individual consumer package is usually the 1-lb size; for the hotel and restaurant trade, the 5 to 10-lb package is the most generally used.

Oysters are generally frozen after shucking and can be packed in a variety of types and sizes of packages which are available and may be selected for this purpose. The tin can has been made use of successfully, as well as several types of paper cups heavily impregnated with paraffin with a closely fitting cover of the same material. Bags of moisture-vapor-proof material fitted into a waxed paper carton have also been used. Care must be exercised to cover the oysters with liquor, since any that are exposed to the air space in the top of the container soon become discolored. It is also necessary that sufficient head-space remain in the can to allow for any expansion in the contents due to freezing. After the oysters have been frozen it is necessary to be sure that they remain frozen until they are in the hands of the consumer and are defrosted only preparatory to cooking.

Table 5. Water Frozen in Fish at Various Temperatures

Temp, °F	Weight frozen, %
30.3	0
30	32
28	61
26	76
24	83
22	86
18	89

Shrimp are frozen in both the green and cooked state. The wholesale trade requires packages of large size. When the shrimp are prepared for freezing they are packed in pans of 1, 5 or 10-lb sizes. The intervening spaces between the shrimp are filled with clear water and the pans are then placed in one of the various types of quick freezers. When they are frozen the cakes formed are removed from the pans by slightly warming the pans. These cakes are then wrapped in some type of water-vapor-proof material and packed in paper cartons. They are then ready for immediate shipment or storage until a market is found for them.

There are a number of packers freezing shrimp individually and, after they are frozen, placing them in packages of sizes required by the trade. This practice requires a somewhat larger container for a given weight of shrimp since it is difficult to obtain as tight a pack after the shrimp are frozen. There is also likely to be more rapid deterioration in storage due to the large air space in the package.

Scallops for freezing should be selected for quality and can be handled in a similar manner to that described above for oysters

and shrimp. As in the case of all other frozen seafoods, deterioration occurs when the package is not tightly sealed against evaporation of moisture.

Crabmeat is frozen after picking from the cooked crabs. It is advisable to freeze it in a sealed and tightly packed package. If attempts are made to freeze it in a package which is loosely packed, heat removal is slow and the quality of the meat may be affected during the process, causing a toughening.

Soft shelled crabs should be individually wrapped before being placed in the freezer since the evaporation of only small amounts of moisture during freezing will adversely affect the quality of the product.

Lobster meat in general can be handled in a manner similar to crabmeat. The same precautions are necessary if a first quality product is to be obtained. In recent years a considerable industry has been built up in the sale of frozen spiny lobster tails. This is not a true lobster and does not have the large claws. The tails are removed from the bodies of the fish and individually wrapped and packed in 10 and 15-lb boxes and frozen. In some instances these tails are boiled prior to freezing. Care should be exercised to hold evaporation of moisture to a minimum in the freezing operation and throughout the storage period, or a toughening of the meat will result.

Table 6. Heat Absorbed in Lowering the Temperature of Various Fish from +60 F to −5 F

Product	Normal water content, per cent	Heat absorbed per lb of product, Btu
Fish fillets		
Cod	83	157
Haddock	82	155
Halibut	75	142
Mackerel	73	138
Salmon	65	123
Shellfish, edible portion		
Clams	86	163
Lobsters	79	149
Oysters	87	165

Clams are handled in a manner similar to that described for oysters.

Storage and Transportation

Investigations have been made in the way of attempts at stopping the action of the enzymes in frozen fish. If it were possible to store fish at a sufficiently low temperature this could be accomplished, but the cost of operation proves prohibitive at such temperatures. The temperatures at which fish are stored vary with economic conditions, but in practically all cases it is advisable to hold the storage rooms at a range of 0 to −10 F.

Table 7. Time Required to Freeze Fish

Thickness of fish, in.	Time required to freeze, min		
	In air at 14 F	In brine at 14 F	In brine at −6 F
0.39	120	12	4
0.79	248	21	8
1.18	361	35	14
1.57	490	54	19
1.97	620	78	29
2.36	748	112	40
2.75	877	148	50
3.15	1000	190	67
3.54	1130	230	85
3.94	1260	275	101

Source: The Preservation of Food by Freezing, Walter Stiles.

It is generally found that fish frozen fast at low temperatures are superior to those frozen at higher temperatures, due to the smaller size of the water crystals formed within the cell structure of the flesh when quick frozen. As a result, the **leakage** from the tissue when the fish are defrosted prior to cooking is reduced to a minimum. The results obtained by rapid or quick freezing are often almost entirely reversed by faulty temperature regulation of the **cold storage rooms**. It is most desirable to hold the temperature of fish storage rooms constant, since very slight changes of temperature permit growth of small to large ice crystals. The damage to the tissue of fish is approximately proportional to the range in temperature. Rooms in which frozen fish are held should be equipped with thermostats set for a varia-

tion of not more than plus or minus two degrees from the temperature selected.

Glazing. Some species of large fish are frozen and stored with only the heads and viscera removed. In others the viscera are removed, leaving the heads on, and still others are left whole. Swordfish, halibut, salmon, and tuna fish are frozen and stored with heads and **viscera removed.** After the fish are removed from the freezer they are dipped into a tank of cold water; the temperature of the fish is low enough to freeze a thin coating of ice over the surface. This is known as glazing. The fish may be

Table 8. Time Required for Ice Glaze to Evaporate from Surface of the Fish

Species of fish	Wt in grams	Wt of glaze, grams	Wt of glaze, % of wt of fish	Duration of glaze, days
Mackerel	434	56	13.0	18
Haddock	964	142	15.3	22
Cod	2588	252	9.8	28
Flounder	293	64	21.9	20
Eel	296	41	13.8	14
Pollock	4270	472	11.1	33

Source: Special Report #7, Walter Stiles.

dipped several times thus increasing the thickness of the coating of ice. In handling large halibut and swordfish a small hoist is usually employed to lift the fish in and out of the glazing tank. They are then piled in the storage room in stacks somewhat resembling a pile of cord wood. The fish can be sprayed with cold water after piling in order to cover them with an additional glaze of ice for protection in case the regular glaze has been cracked in handling. At frequent intervals during the period of storage, the piles are examined and the **spraying** operation is repeated when it is observed that the glaze has become thin from evaporation or has cracked from handling, exposing the surface of the fish to drying atmosphere of the storage room. This reglazing is repeated in some instances as often as every three weeks when it is found that rapid evaporation has removed a large portion of the glaze from the surface.

The rapidity with which the evaporation of the glaze occurs, depends upon the humidity of the air in the storage room. The higher the humidity the longer the glaze will remain on the fish. It is recommended that the humidity in the storage room be held at as near the saturation point as possible. **Table 8** shows the approximate length of time a glaze may be expected to remain on fish in a cold storage room.

The stacks of fish should be well separated in order that the inspection and reglazing may be accomplished with as little difficulty as possible. The size of the storage room governs to some extent the space to be left between piles. Under ordinary conditions the distance varies between 20 to 30 in. Another consideration is to allow an 8 to 10-in. space between the stacks of fish and the outside walls, if the storage room is situated in the outside tier of the warehouse. Particularly is this necessary where the room is on the south side of the building. (See Chapter 10.)

Icing unfrozen fish for the purpose of preservation until sold in the fresh market or placed in the freezer for future use has been practiced for approximately 100 years. It is the best preservative which has been devised, since the ice not only holds the temperature, but keeps the surface of the fish moist and in good condition. Various preservatives have been added to ice in attempts to prolong the period over which fish can be kept in good condition. Not any of these have been found to be effective enough to be economical. During the past few years storage rooms have been designed for sufficient **mechanical refrigeration** to hold the temperature between 32 and 35 F for storage of fish prior to packing for shipment or freezing. Only sufficient ice is used in the containers of fish to keep them moist. This practice should become more generally used since it not only holds the fish in good condition over a longer period of time but prevents the loss of valuable minerals from flesh through leaching. In a room so equipped the ice melts slowly and moistens the surface but not fast enough to cause any considerable volume of water to be produced. It is economical since the quantity of fish lost through spoilage is reduced, the vol-

ume of ice necessary is reduced, and a lower temperature than it is possible to obtain with ice alone keeps the fish in better condition.

There are a number of suggestions for general practice which are worth consideration. Fish is one of the most tender of any of the food commodities and should be given extra careful consideration as such. **Finely crushed ice** is preferable to large pieces for packing fish in boxes. The size of the container may vary from a 50 to a 500-lb box; the larger sizes are usually edges and there is no damage to the flesh of the fish from bruising or scratching.

The boxes are **packed** in layers alternating between fish and ice, a layer of ice on the bottom, then a layer of fish followed by a layer of ice, repeated until the box is filled. The layers should be so arranged that a layer of ice is on the top of the fish. The cover is then placed on and the box is ready for shipment.

It is not possible to estimate the quantity of ice necessary to hold the fish over a given period of time since this is almost

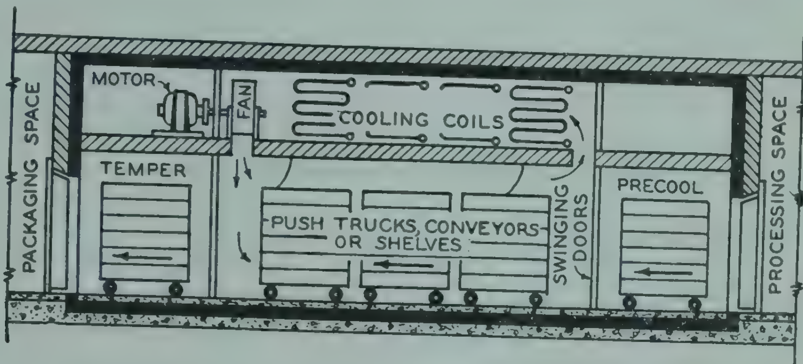

Fig. 5. Freezing Fish on Hand Conveyor Trucks.

used for large fish such as halibut, tuna and swordfish. Regardless of the size of the fish it is tender and easily bruised. The finely crushed ice does not tend to bruise and dent the fish as much as is the case with large pieces of ice.

There are a number of machines available, in both large and small units, which manufacture ice in various forms. One of these machines is that which freezes a fine spray of water in separate particles resulting in a snow. Since there are only small crystals formed by this method there is no need for a crushing machine to prepare ice for use with fish. The particles are so small that there is little chance of damage to the fish by bruising. Another of the machines freezes a film of water on a drum. The film breaks into small pieces and eliminates the necessity of crushing the ice for use in packing fish. Still another of these machines freezes a film of water into a ribbon which breaks into small pieces from handling. These latter two machines manufacture ice without sharp corners or entirely dependent upon the outside temperatures. The transportation firms are required to **re-ice** shipments of fish, during the warm weather, at least once each 24 hr while the shipment is enroute to its destination. Recently, insulated containers for use in making less than car lot shipments have been placed on the market for the use of the general public. It is not necessary to re-ice this type of shipment. These containers are not sold, but are leased to shippers of perishable foodstuffs while ownership is retained by the manufacturers. They are heavily insulated and are built in several sizes; some of these are equipped with a cover attachment and can be used in the retail stores for display of either frozen or unfrozen seafoods.

In transporting either frozen or unfrozen seafoods in **refrigerator cars,** the same care in packing to insure free circulation of air as was mentioned above for cold storage rooms is necessary. Refrigerator cars using ice as the medium of refrigeration for shipping frozen seafoods require a lower tem-

perature than is possible to obtain by ice alone. Salt in varying proportions to the ice produces temperatures low enough to hold the seafoods frozen. The following table gives the approximate temperature obtainable with mixtures of salt and ice in the proportions by weight shown (see also page 118):

Salt in mixture, %	Temperature of mixture, °F	Salt in mixture, %	Temperature of mixture, °F
0	32	15	12
5	27	20	1.5
10	20	23	−6.3

The ice should be broken up rather than used in the large cakes as received from the freezer since the fine ice is caused to melt more rapidly by the salt than the coarse pieces. Any grade of commercial salt is suitable for this purpose; it should be of fairly large grain such as the common ice cream salt.

When making shipments of frozen fish from the warehouse in refrigerator cars or trucks, the order for the conveyance should be placed with the carrier in sufficient time to be sure that it is properly cooled prior to loading. Unless it is possible to obtain precooled cars and trucks from the carrier, at least 24 hr should be allowed for **precooling** before the loading operation is begun. The ice bunkers should be loaded with a mixture of 30 lb of salt to 100 lb of ice while the car is closed. It is desirable to load the lower part of the ice bunker with fairly large pieces of ice and the top part with the smaller ones; the salt should be mixed throughout the ice so that it can react with the ice more readily. The actual loading operation should not be started until the temperature inside the car has reached at least +20 F. The loading operation should be completed with as little delay as possible. If for any reason the loading is interrupted before completion, the doors of the car should be tightly closed pending the completion of the work. The temperature should be held at between 10 and 15 F throughout the entire trip. Upon arrival at its destination the car should be unloaded as rapidly as possible

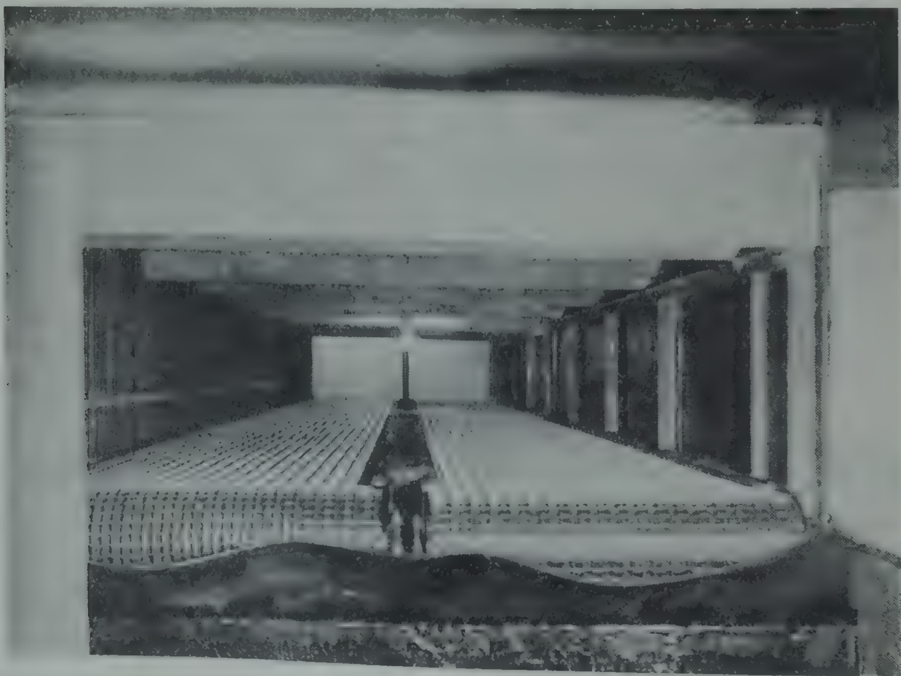

Fig. 6. Conveyors in a Freezing Tunnel at Mobile, Ala., Capable of Handling 2000 lb of Fruit, Vegetables, or Seafood per Hour.

and the contents placed in low temperature storage rooms. If for any reason the unloading operation is not completed at one time the doors of the car or truck should be tightly closed until work is resumed.

Packing for Shipment

Packaging. A great variety of seafoods is prepared in the packaged form. One of the largest classes is fillets of fish which are usually prepared for storage in 1 to 10-lb paper packages placed in corrugated **paper cartons.** Since the products contained in this type of package are prepared by covering with one of the various wrappers which are impervious to the drying atmosphere of the freezer, it is not necessary to be concerned with the development of freezer burn or desiccation.

This type of package is so well insulated by the dead air spaces inside the corrugations of the latter that there is little cause to fear thawing during transfer from the point of freezing to the warehouse unless the cartons are separated by considerable distance. There is, however, some danger of complete or partial **thawing** when several hours or days are required for the transfer from one warehouse to another. The damage may become serious if the contents of a carton are slightly softened upon arrival at the warehouse and are not promptly placed in the cold storage room. In such cases, it is well to leave space between the cartons in a stack for the free circulation of cold air. While the cartons provide insulation against the warm outside air, they also insulate against the desired refrigeration of the storage room. Several days may elapse before sufficient heat has been absorbed to refreeze soft fillets, even weeks if the package is placed in the center of a tightly stacked pile. During this period, spoilage may have progressed to a point at which the contents of the package are unfit for consumption.

Another type of container used for packing frozen fishery products is the **wooden box** or barrel. Methods of handling are much the same. Boxes should be stacked to provide space between layers and rows of boxes, in order to insure circulation. Because of the shape, barrels cannot be packed in piles tightly enough to prevent fairly free circulation of the air. The wood of the boxes and barrels does not furnish so efficient an insulation as does corrugated cardboard. The fish stored under cold storage should be protected at all times by a **coating** of some material, either a glaze of water ice or a wrapper.

The pipe coils for the heat absorption in fish storage may be any one of several types which, for economy of space and operation, are suspended from the ceiling of the room. This permits a circulation of the cold air from the coils to the fish by convection currents without the necessity of mechanical means for air circulation. The provision of cooling surface should be sufficient to insure a constant temperature low enough to hold the fish in good condition.

Engineering practice dictates the requirements for mechanical equipment and insulation. Recognition of climatic conditions must be considered in calculating the necessary and economical refrigeration surface and thickness of insulation.

Packing Shellfish

Shellfish are usually handled by methods similar to those reviewed above, with the possible exception of scallops. Those which are shipped in the shell are susceptible to rises in temperature and will die if they are permitted to become warm during handling or transit to the market. When these shellfish are removed from the water they close their shells until death occurs. It is possible, by this means, to separate the dead ones from those which are alive, for those having open shells are unfit for use. During extremely cold weather, precautions are necessary to prevent freezing of live shellfish in transit.

Shellfish should be washed so as to remove all the adhering particles of mud and sand before the shells are removed, a process which does a great deal toward eliminating one of the causes of bacterial contamination.

In the past the shippers of live lobsters and crabs have frequently experienced excessive losses through the death of the entire or a large proportion of the shipment of these seafoods. In many instances they

were at a loss to explain high mortality. Upon investigation, however, in nearly all cases of excessive loss it was found that the shipments of the lobsters and crabs had been made in the same express car with frozen fish refrigerated with dry ice.

Table 9. Estimate of the Probable Storage Life of Frozen Fish[1]

Species	Round or headed and gutted	Packaged fillets
	Months[2]	Months[2]
Butterfish	6– 8	10–12
Cod	8–10	10–12
Croakers	6– 8	8–10
Flounder	8–10	10–12
Grouper	6– 8	8–10
Haddock	8–10	10–12
Halibut	8–10	10–12
Lake herring	6– 8	8–10
Lingcod	6– 8	8–10
Mackerel		
(Spanish)	6– 8	6– 8
(Boston)	6– 8	6– 8
Mullet	6– 8	8–10
Porgie (Scup)	8–10	10–12
Pollock	8–10	10–12
Pike (all species)	6– 8	8–10
Rosefish (ocean perch)	6– 8	8–10
Red snapper	6– 8	8–10
Rockfish	6– 8	6– 8
Salmon (except pink)*	6– 9	6– 9
Sole	8–10	10–12
Smelt	8–10	8–10
Sablefish	6– 8	8–10
Sea trout	6– 8	6– 8
Shrimp	6– 8	8–10
Whiting	8–10	10–12
Whitefish	8–10	8–10

* Pink salmon does not keep well when wrapped.

[1] It is often of value for a warehouse operator or a frozen fish producer to obtain an idea of the period of time that his product can be expected to remain in a salable condition. The above table contains such an estimate expressed in months in storage. The times shown in the table are based on the assumption that the fish were in first class condition when landed and that they were prepared and frozen without delay. It should also be understood that the temperature in the storage room is held at a minimum of fluctuation and other approved conditions. The estimated times are based upon experimental data and general commercial practice.

[2] Storage period is based on 0°F temperature. Lower temperatures will extend the storage period beyond that shown.

Dry ice is solid carbon dioxide, and while it is not toxic it is heavier than air and tends to settle to the bottom of the car, thus excluding the oxygen and smothering the live lobsters and crabs. It is advisable to refrain from shipping either of these seafoods alive in a closed express car with shipments of frozen fish packed with dry ice.

Scallops which are taken in deep water are usually shucked aboard the boat, the shell and viscera discarded at sea, and only the large adductor muscle retained for food. These are then placed in the shipping container and packed in ice ready for shipment. Scallops taken in the shoal waters are usually carried to a shucking house where the meats are removed and prepared for shipment to the market. The strictest of sanitary rules should be observed.

Crabs are prepared for market in several ways, depending upon the type of crab—whether soft or hard; and upon whether they are alive or cooked. Live, hard-shell crabs are usually shipped in barrels or baskets with sea weed and a small amount of crushed ice for refrigeration. Later they are steamed in large retorts and the meats picked at the wholesale or retail market. When crab meat is prepared for market at the point of production, it is removed from the cooked crabs and packed in 1-lb tin containers having holes in the bottom. These containers are fitted with tight covers and are packed in boxes or barrels and covered with crushed ice. A piece of burlap is usually used as a cover for the barrel. Soft-shelled crabs are handled with the greatest of care since they are much more subject to injury than the hard variety. They are prepared for shipment to market by packing carefully in trays holding one or two dozen crabs; these trays are then packed in large crates. The crabs are surrounded with wet sea weed and refrigerated with ice.

Lobsters are usually shipped alive, and care is necessary to prevent death due to fresh water from melting ice used as a refrigerant. The lobsters are packed in small barrels in green sea weed which is moistened with sea water. This small barrel is centered inside a larger barrel and made fast, the space between the two barrels being filled with large pieces of ice. Lobsters are usually marketed in the live state. Although there is a limited quantity of lobster meat available in the market, it is prepared in a manner similar to the method

described for preparing crab meat. It should be kept thoroughly chilled from the time it is picked until it reaches the consumer. Like crab meat, lobster meat which is adequately packaged, may be stored frozen for 3–4 months.

Shrimp are prepared for market by several treatments. Only the tails are of value as food. Green shrimp are those which are marketed without any preparation except washing; they are shipped in barrels, half barrels or 100-lb boxes, with ice in the bottom and on top of shrimp. The "cooked or steamed" shrimp are prepared by boiling in a light brine solution, and can be handled either with or without the shell. They are packed for shipment in 1 to 5-gal tin containers fitted with a tight top. These containers are packed in barrels or boxes and surrounded with crushed ice. The barrels are covered with burlap; the boxes are covered with a solid wooden top.

Calculation of Refrigeration Requirements

When fish are received at a cold storage warehouse in the unfrozen condition packed in ice, and are to be frozen before being stored in the warehouse, it is necessary for the operator to estimate the quantity of refrigeration required to freeze them. It will be noted in Table 1 that fish contain a considerable portion of water. In making the calculation of the refrigeration required, for practical purposes the solids can be disregarded, since they are so low.

If 100 lb of alewives are delivered to the warehouse packed in ice at 50 F and are to be frozen and stored at a temperature of 10 F the refrigeration capacity required for this will be calculated as follows:

Since it is necessary to absorb 1 Btu per lb for each 1 F,
$50° - 32° = 18 \times 100$ lb of fish to be lowered to 32 F $= 1800$ Btu
144 Btu per lb is to be absorbed to freeze the fish at $32° = 14{,}400$ Btu
0.5 Btu per lb to lower the temperature from 32° to 10 F,
$100 \times 22 \times 0.5 = 1100$ Btu
$1800 + 14{,}400 + 1100 = 17{,}300$ Btu.

Since, however, there is only 74.4 per cent moisture to be frozen in the alewives, then the heat removal to freeze them and lower to 10 F will be 74.4 per cent of $17{,}300 = 12{,}871$ Btu. In this calculation no allowance has been made for heat losses of the freezer and storage room; these losses will be added to the required refrigeration. In these calculations only the figures in round numbers for required refrigeration are used.

Summary

Fish which are frozen for future markets should be carefully selected. Only those in prime condition should be frozen.

The fish should be frozen immediately when received at the cold storage plant and be held in this condition until finally delivered into the hands of the consumer.

In instances where, for any reason, the frozen fish have defrosted enroute, extra care is required in refreezing them. Only those which are in prime condition should be refrozen. The refreezing should be accomplished as rapidly as possible.

The temperature of the cold storage room should be maintained at between 0° and −10 F, with great care to limit the range to as narrow a margin as is possible. It is advisable to control the temperature automatically with a thermostat.

Boxes or cartons containing frozen fish should not be piled in the storage room so that the air can circulate freely among them. This is to avoid desiccation, but open-stacking may be used temporarily if softening has occurred in transportation or handling. Care should be exercised in stacking the piles well away from the walls if the storage room has an outside wall or is near a room maintained at a higher temperature.

A heavy glaze of ice should coat the surface of all fish frozen in the round which do not have a wrapping of some moisture-vapor-proof material. Frequent examination of the glaze should be made and reglazing done as often as is necessary to prevent exposure of the surface. The water used for reglazing should be near freezing temperature when sprayed upon the surface of the fish.

When refrigerator cars are to be loaded with fish from cold storage, it is advisable to precool them thoroughly before the loading is begun. When the temperature of the cars has reached approximately +10

to +15 F, the loading is begun and should be accomplished as rapidly as possible. When a car is received at the warehouse, it should be completely unloaded with as little delay as possible.

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If you searched this chapter for something which was not found in it, please let the editors know.

4. ICE CREAM

THE refrigeration required at the several stages in the manufacture and distribution of ice cream and other frozen desserts varies with their composition. The manner in which the refrigeration is applied and maintained affects the quality of the products. The refrigerating engineer is, therefore, interested in such general background information on the composition and manufacture of these products as will enhance his understanding of the amount of refrigeration required and the ideal manner of its application.

Composition of Ice Cream

Ice cream is by far the leading frozen dessert. Practically all ice cream manufacturers also make some sherbets and ices, and many make frozen suckers during the summer season. In some states the manufacture of ice milk is permitted. Accordingly, frozen desserts cover a wide range in composition. Ice cream itself is varied in composition under the influence of such factors as the individual standards by states, and the judgment of manufacturers as to the most successful relationship among composition, quality and costs, as against selling price, competitive conditions, consumer purchasing power and volume of sales.

In discussing the composition of these products, a distinction should be made between practices in normal times and practices that prevailed under wartime restrictions. In order to conserve milk solids for other uses which were considered more nearly essential, the ice cream industry operated under restrictions which limit the amount of milk solids each manufacturer could use. A quota was established as determined by a percentage of the milk solids used by the manufacturer during a base period. In order to stretch this quota as far as possible so that troublesome rationing might be avoided, the restrictions also limited the richness of ice cream by imposing a milk solids content maximum. In the following discussion of composition the treatment is intended to refer to normal practices, followed by a brief statement of trends under wartime restrictions.

Standards. The standards for ice cream of the various states are written chiefly in terms of fat content, with some states also specifying minima for either the total milk solids content or the milk-solids-not-fat (serum solids) content. The majority of states also control the amount of air in the product either by specifying a minimum weight per gallon, or a minimum weight of food solids per gallon, or a minimum volume after the air has been removed on melting.

The fat standards range from 8 to 14 percent for plain or vanilla ice cream. For ice cream flavored with the more bulky flavoring materials such as fruits, nuts, and chocolate syrup, most states permit two per cent less fat, to enable manufacturers to use one stock mix in making the various flavored ice creams. Accordingly, the minimum fat standards for fruit, nut and chocolate ice cream range from 6 to 12 percent.

Milk fat content. Legal standards for ice cream are in terms of the milk fat or butterfat content. Where other ingredients such as eggs, nuts, cocoa or chocolate contribute fat, such fat cannot be considered as satisfying the legal minimum. The discussion of fat content is, therefore, solely in terms of milk fat or butterfat.

HUGO H. SOMMER, Author Chapter 4. Born 9/4/96 in Timothy, Wis. Educated at Univ. of Wisconsin, BS, 1918; MS, 1919; PhD, 1922.
Formerly Asst., Agric. Chemistry Dept., Univ. of Wisconsin, 1917–19; Chief Chemist, Northern Calif. Milk Producers Assn., 1920; Dept. of Dairy Industry, Univ. of Wisconsin, Asst. Prof. 1920–23; Assoc. 1923–27; full Professor to date.
Author of "Theory and Practice of Ice Cream Making," 1932–35, 38, 44, and 46; "Market Milk and Related Products," 1938–46. Received the Borden Award in Dairy Manufacturers, 1942. Member of Amer. Chemical Society; Amer. Assn. for the Advancement of Science; Intl. Assn. of Milk and Food Sanitarians; Amer. Dairy Science Assn.; Alpha Zeta; Phi Lamba Upsilon; Sigma Xi; Gamma Alpha.
At present he is Professor, Dept. of Dairy Industry, Univ. of Wisconsin.

In states having higher fat standards, most ice cream is made with a fat content near the legal minimum. In states with the lower standards, it is a fairly common practice among manufacturers to make two grades of ice cream, one a competitive ice cream with a low fat content and usually a high overrun, and another a higher quality product, richer in fat and lower in overrun. To a limited extent ice cream is made with a fat content considerably higher than even the highest state standards by manufacturers who appeal to a special trade at premium prices. Such ice cream may be made with fat content of 16 or 18 percent, and in rare instances as high as 22 percent. Thus, if we include the extremes, the range in fat content is from 6 to 22 percent, although the bulk of ice cream is made with fat content ranging from 10 to 13 percent. Under wartime restrictions the most common range was from 9 to 11 percent.

Serum solids content. The term "serum solids" is universally used in the ice cream industry to designate the non-fat solids from milk. The chief components of milk serum are lactose, the milk proteins (casein, albumin and globulin) and milk salts (sodium, potassium, calcium and magnesium as chlorides, citrates and phosphates). The proportions in which these components occur in milk vary with such factors as the fat content of the milk, stage of lactation of the producing cows, and to some degree, feed conditions. For the purpose of general calculations the following average composition percentages for serum solids are useful: Lactose, 54.5; milk proteins, 36; milk salts, 9.5 percent.

The serum solids in ice cream tend to produce a smoother texture, better body, and better melting characteristics. Usually serum solids are relatively inexpensive as compared with fat, and so the tendency is to use them liberally. This practice is meritorious from a nutritive standpoint. Two considerations impose a limit on the serum solids content: (1) The total solids content of ice cream must be kept within reasonable limits, otherwise the product tends to be soggy and pasty; (2) the lactose content, which is 54.5 percent of the serum solids, must be kept below the limits where lactose crystallization results in sandiness. The occurrence of sandiness in ice cream is fairly complex; it involves not only the lactose-to-water ratio in the product, but also the temperature at which the frozen ice cream is held and the length of time it is held.

For average conditions of turnover in the manufacture and sale of ice cream, a lactose-to-water ratio of 1 to 10.8 is safe, from the standpoint of sandiness. It is more practical to state this limit in terms of serum solids, and, on the basis of a 54.5 percent lactose content in serum solids, this ratio is equivalent to saying that the product must contain 5.9 lb of water for every pound of serum solids. Where ice cream is sold within five to seven days after it is frozen and hardened, the serum solids content can be increased considerably beyond this point, e.g., only 5.4 lb water per lb serum solids.

The serum solids content should not be increased to the maximum permitted by the above considerations in ice cream with a high content of other solids (as in ice cream with a high fat content); otherwise a soggy, pasty product results. The total solids content commonly is kept slightly below 40 percent, and certainly should not exceed 42 percent.

The lower limit in the serum solids content, viz., 6 to 7 percent, is found in ice cream where the only dairy ingredients are milk and cream—a home-made type of product. Ice creams with an unusually high fat content will also be kept near this serum solids content in order that the total solids content may not be excessive. Most ice cream, however, is made with the addition of condensed or powdered milk or skim milk in such amounts as to bring the serum solids content within the range of 10 to 11.5 percent. The upper extreme of 12 to 14 percent serum solids can be used only where sandiness is avoided by a rapid turnover or other special means.

Under wartime restrictions the serum solids content was limited. It could not exceed 80 percent of the fat content.

Sugar content. The sugar content of ice cream is of special interest because of its effect on the freezing point of the mix and the hardening behavior of the ice cream.

The extreme range of sugar contents encountered in ice cream is from 12 to 18 percent, with the range of 14 to 16 percent being most representative of the industry. The chief sugar used is sucrose (cane or beet sugar), but even before the war many manufacturers were using dextrose and corn syrup solids to replace part of the sucrose. Under wartime sugar quotas the use of dextrose and corn syrup solids, both in syrup and powdered form, has increased. In some instances 50 percent of the sucrose content has been replaced by such other sweetening agents. A more normal practice is to replace from one-fourth to one-third of the sucrose by dextrose or corn syrup solids, or a combination of the two. The kind of sugar used, as well as the amount, is of interest in connection with the freezing characteristics of the product.

Stabilizers. Practically all ice cream is made with the addition of a **stabilizer** to aid in maintaining a smooth texture, especially under the conditions that prevail in retail cabinets. The few manufacturers who normally do not use stabilizers offset this omission by a combination of factors such as a high fat and solids content, the use of superheated condensed milk to aid in smoothening the texture and imparting body, and a sales program designed to provide rapid turnover.

The stabilizing substances most commonly used are gelatine and sodium alginate, a product made from the giant kelp gathered in the waters off the coast of California. Other substances used less commonly are locust or carob bean gum, gum arabic or acacia, gum tragacanth, gum Karaya, psyllium seed gum, and pectin. The amount of stabilizer commonly used in ice cream falls within the range of 0.20 to 0.35 percent of the mix weight.

The amount and kind of stabilizer used affects the viscosity characteristics of the mix as influenced by temperature. Accordingly, this subject is of interest in heat transfer computations as in cooling over a surface cooler.

Eggs in ice cream. Egg solids either in the form of fresh whole eggs, frozen eggs or powdered whole eggs or egg yolk are used in ice cream by some manufacturers. While flavor and color may be motivating factors in this choice, the most common reason for their use is to aid the whipping qualities of the mix. To obtain this result to a worthwhile degree the amount required is about 0.25 percent egg solids, and 0.50 percent is about the maximum content employed for this purpose. It is the egg yolk that imparts this property, and to obtain the desired result the egg yolk should be present in the mix at the time it is being homogenized.

In frozen custards or "New York" ice cream the presence of eggs in liberal amounts and the resulting yellow color are identifying characteristics. Some state standards specify a minimum egg content for these products.

Cereal products in ice cream. In the normal production of ice cream, starchy cereal products are not used. Some consumers on observing the smooth texture of commercial ice cream and not knowing that homogenization of the mix and efficient freezing and hardening methods are the important factors in attaining this result, have in the past assumed that the smooth texture was indicative of starch. Apparently such ideas find their origin in recipes for home made ice cream where starch is commonly included. In general the ice cream industry has resented such impressions and has scrupulously avoided such a practice in normal times. In fact, many state standards make no provision for the use of starchy cereal products or expressly prohibit their use.

Under wartime restrictions on the amount of milk solids and on their percentage level in ice cream some manufacturers resorted to the use of starchy cereal products in an effort to approach the body and texture they normally had in their product. This practice has by no means become universal. It has developed to the greatest extent in areas where the allotments or quotas were grossly inadequate because of population increases as compared with the base period. The products which have come into limited use are oat flour, rice flour, soybean flour, corn starch and dextrinized starches. Where such products are used the amount ranges from 1 to 3 percent.

Milk ices or ice milk. A limited number of states permit the manufacture and sale of ice milk. This type of product commonly contains 3 to 4 percent fat, 13 to 15 percent serum solids, and the practices with respect to sugar and stabilizers are very similar to ice cream practices. The sugar content tends to be somewhat higher in order to build up the total solids content, and the stabilizer content is higher than in ice cream, approximately in proportion to the higher water content (lower total solids content) of ice milk.

Composition of sherbets. Sherbets are fruit- (and mint-) flavored frozen desserts containing some milk solids and characterized by their high sugar content and tart flavor. While the milk solids can be supplied by the use of milk, the general practice is to supply them by using ice cream mix. A typical procedure is to prepare a solution of sugars and stabilizer in water in such a manner that it serves as a base for the making of sherbets of various flavors. To 70 lb of such a sherbet base, 20 lb of flavoring materials and 10 lb of ice cream mix are added.

The sugar content of sherbets ranges from 25 to 35 percent, with 28 to 30 percent being most common. Because of the high sugar concentration, crystallization of the sugar, especially at the surfaces of the frozen product, occurs if this sugar content consists entirely of sucrose. This crystallization is avoided by employing dextrose or invert sugar to furnish at least one-fourth of the total sugar content. The sherbet base is prepared by dissolving the stabilizer and sugars in water in such a manner that the desired sugar content, both as to amount and combination of sugars, is achieved in the finished product. Recognition and allowance is made for the sugars contributed by the ice cream mix and the fruit preparation which will be included to produce the final product.

In the above proportions the 20 lb of flavoring materials will consist of fruit juices or purees, possibly flavoring extract and color, edible acid to produce tartness, and water as necessary to bring the mixture up to the desired weight. Normally citric acid in the form of a 50 percent stock solution is used to provide the tart flavor. An acidity of 0.35 to 0.45 percent, expressed as lactic acid, in the finished product is the tartness usually desired. Tartaric acid is also used for this purpose, and when neither citric nor tartaric acid is available, lactic acid, and even saccharic acid have been used. These acids are edible in the concentrations employed and are metabolized by the body. Even phosphoric acid has been used as an emergency supply, and while it may well be considered edible at this concentration, objections to its use have been raised because inorganic acids obviously will not be metabolized and will therefore tend to deplete the alkaline reserve of the body. The small amount of the concentrated acid solution that is employed to provide **tartness** is usually withheld from the mixture until the freezing has progressed to some extent in the interest of preventing curdling of the casein from the milk solids.

In some areas vanilla and chocolate-flavored sherbets have been made without the tartness of flavor which should characterize sherbets. Accordingly these products are generally not considered as legitimate sherbets, but rather as sub-standard ice cream or ice milk.

In sherbets, and even more so in ices, a high overrun is not desirable, otherwise they will appear foamy or spongy under serving conditions. The overrun should be kept within the limits of 25 to 40 percent. This fact and the problem of preventing "bleeding," the leakage of syrup from the frozen product, directs the choice of stabilizers as compared with ice cream. If gelatine is to be used as the stabilizer in sherbets, the freezing conditions must be so managed as to avoid an excessive overrun. Sodium alginate as now available is not compatible with the relatively high acidity in sherbets. For these reasons, the gums which were mentioned in connection with ice cream are most commonly used as the stabilizer in the case of sherbets and ices.

Composition of ices. Ices contain no milk solids whatever, but in other respects closely resemble sherbets. To offset the lack of solids from milk, the sugar content of ices is usually slightly higher than in sherbets; commonly the sugar content is

30 to 32 percent. A combination of sugars should be used to prevent crusty sugar crystallization just as in the case of sherbets. The usual procedure is to make an ice base in the form of a solution of the sugars and the stabilizer, from which different flavored ices may be prepared by adding the flavoring material in the same general manner as described for sherbets.

Ices, containing no ingredients with lubricating qualities, cause extensive wear on the scraper blades in the freezer. Frequent resharpening of the blades is necessary. Where a number of freezers are available, and the main production is ice cream, it is desirable to confine the freezing of ices and sherbets to a specific freezer or freezers, which should then receive special attention with respect to resharpening of the blades.

Frozen suckers. The mix for these products is essentially the same as for ices. The mix is placed in suitable molds which also hold sticks or other "handles" dipping into the mix. The filled molds on a conveyor pass through a cold brine bath, immersed to a suitable depth, with the rate of travel so adjusted in relation to brine temperature that the mix is frozen completely in this passage. The frozen suckers are then loosened from the mold by applying momentary melting in a water bath; they are removed from the mold, wrapped or placed in envelopes, and are then ready for frozen storage and distribution. The freezing is done without agitation, and there is, therefore, no overrun. Under such freezing conditions, the ice crystalline structure is apparent, and, to keep it as fine as possible, the stabilizer content is chosen somewhat higher than for ices. To facilitate the freezing and avoid too ready melting, the sugar content is chosen somewhat lower than for ices.

Making the Ice Cream Mix

On the basis of considerations already discussed in brief, the ice cream manufacturer has chosen the composition of his product in terms of **percentage composition.** For example, the chosen composition for a typical ice cream would be

Fat—12.5 percent
Serum solids—10.5 percent
Sugar—15.0 percent
Stabilizer—0.3 percent.

The next step is to select the **ingredients** which are to be used to achieve this composition. After the sugars and stabilizer have been chosen, they are obtained as such, except that in the case of sugar, some of it may be derived from sweetened condensed milk if this product is one of the dairy ingredients.

The **fat and serum solids content** must be obtained from dairy ingredients, and here there is considerable latitude in the choice. In general the mix must include at least one product from each of three general classes of proucts:

I. Products rich in fat
   1. Cream, usually 40 percent fat, but may range from 18 to 50 percent
   2. Plastic cream, 72 to 80 percent fat
   3. Frozen cream, 40 to 50 percent fat
   4. Unsalted butter, 83 to 84 percent fat
   5. Butter oil

II. Products rich in serum solids
   1. Plain condensed milk, usually 8 percent fat, 20 percent serum solids
   2. Plain condensed skim milk, usually 30 to 34 percent serum solids
   3. Sweetened condensed whole milk, 8.5 percent fat, 19.5 to 20.0 percent serum solids, 41 to 43 percent sugar
   4. Sweetened condensed skim milk, 0.3 percent fat, 28 percent serum solids, 41 to 43 percent sugar
   5. Non-fat dry milk solids, 1.0 percent fat, 95 percent serum solids
   6. Condensed sweet buttermilk, 2.5 percent fat, 30 to 32 percent serum solids.

III. Products of intermediate fat and serum solids content
   1. Milk—the fat content may range from 3 to 5.5 percent, and the serum solids content varies with the fat content on an average in accordance with the following: Serum solids content $= 8.27 + 0.4$ (fat test—3.0)

2. Skim milk—with efficient separation the fat content should be less than 0.1 percent, usually 0.06 to 0.1 percent. The serum solids content varies with the richness of the parent milk, and on an average follows the formula: Serum solids in skim milk = 8.53 + 0.5 (fat test of milk—3)
3. Sweet buttermilk, 0.6 to 1.0 percent fat, and serum solids similar to skim milk.

The choice of the dairy ingredients is made on the basis of their effect on the quality of the ice cream, comparative costs, and the availability of the ingredients at the time and place in question. In general the highest quality, especially from the standpoint of flavor, is obtained from the use of fluid, fresh ingredients. However, in times of shortage and in areas where local supplies are inadequate, the choice naturally goes to products suited for longer shipment and storage. In any case the mix is computed on the basis of the composition of the ingredients so as to achieve the chosen percentage composition of the mix.

Mixing and pasteurizing. The general procedure is to place the liquid dairy ingredients in a pasteurizing vat that is equipped with suitable means of agitation, especially to keep the sugar in suspension until it is dissolved. The dry ingredients are then added, with suitable precautions to prevent lump formation in the case of such products as stabilizers, non-fat dry milk solids, powdered eggs, cocoa, etc. Gelatine should be added while the temperature is still low so as to allow time for the gelatine to imbibe water before solution is promoted by heat. In general dry ingredients that tend to form lumps may be added successfully by first mixing with some of the sugar in the dry form so that moisture may penetrate freely. Where the vat agitation is not fully adequate, the sugar may be withheld until the liquid portion of the mix has been partly heated so that promptness of solution avoids settling out.

The mix is pasteurized to destroy any pathogenic organisms that might be present, to lower the bacterial count so as to enhance the keeping quality of the mix and possibly to comply with bacterial count standards, to dissolve the dry ingredients, and to provide a temperature suitable for efficient homogenization. A pasteurizing treatment of 145 F maintained for 30 minutes is fully adequate, and the general practice is to use temperatures of 145 to 150 F, and less commonly as high as 155 F. The mix should be homogenized at the pasteurizing temperature, and the vat batches should be small enough in relation to homogenizer capacity that homogenization can be completed in one hour, preferably less.

Homogenizing the mix. The purpose of homogenization is to disperse the fat in a very finely divided condition. In milk and cream most of the fat is in the form of globules that are 3 to 7 microns in diameter, and some of the globules are as large as 10 or 12 microns in diameter or larger, especially if there has been some churning incidental to handling. In a properly homogenized mix there should be very few if any globules over 2 microns in diameter, and most of the fat should be in globules of 1 micron or less. The homogenizer achieves this condition by pumping the mix under high pressure, 2000 to 3500 lb per sq in., through a controllable homogenizer valve which has been throttled down so as to create the desired back pressure. In the homogenizer valve the fat is dispersed by virtue of the shearing action to which the high velocity stream subjects suspended particles. In most homogenizer valves this shearing action is provided by having the stream confined between two closely spaced parallel surfaces in the form of a valve seat and valve plug, carefully ground to a mutual fit. Pressure is regulated by the throttling action applied to the plug by means of a spring-loaded stem. The high velocity stream causes wear of these surfaces which results in grooves or channels, even though extremely hard alloys are chosen for the parts; consequently, resurfacing of the valve seat and plug must be done at fairly frequent intervals to maintain efficient homogenization.

To overcome a possible inefficiency in shearing because of a core effect in the stream between two parallel surfaces, and to simplify valve maintenance, a radically different type of valve has been recently

introduced. In this new valve, turbulent flow through restricted spaces is deliberately provided in the form of a cone-shaped highly compressed wad of stainless steel wire, held in a suitable seat with the apex of the cone down toward the hole through which the mix enters. Pressure is regulated by the throttling effect of a spring-loaded stem applying a flat surface against the base of the cone shaped wire wad. The mix passes as a turbulent stream through the compressed wire wad. The preformed wire wads are intended for single service, so that the machine can easily be maintained at maximum efficiency.

In homogenization there is a tendency for the small globules to cohere into "clumps." Under the microscope these clumps are seen as irregular-shaped masses, almost amorphous in appearance; and their maximum dimension may be 10 to 20 microns and even larger. Such clumps cause a high mix-viscosity, and interfere with whipping qualities and the production of a smooth texture almost as much as the large globules of unhomogenized or inefficiently homogenized mix. The question of the size to which the fat globules are subdivided is determined by the homogenizing pressure and by the efficiency of the valve, but in the question of clumping other factors become involved. The factors which **affect the clumping of fat** are briefly as follows:

I. Factors that favor fat clumping
   1. High homogenizing pressure
   2. Low homogenizing temperature
   3. High fat content in the mix
   4. High acidity in the mix
   5. A high content of calcium and magnesium salts as compared with the citrate and phosphate content.

II. Factors that tend to prevent clumping, in addition to the converse of the above factors
   1. The use of egg yolk in the mix
   2. The use of sodium alginate through its tendency to form insoluble calcium alginate.

Control of clumping is exercised through these factors or by the use of two-stage homogenization. The first stage or valve applies the more severe treatment to cause the fat break-up, and the second stage is less severe so that there is substantially no additional fat break-up, but merely disruption of any clumps that formed in the first treatment. Commonly used pressures are 2000 to 2500 lb per sq in. across the first valve, and 500 to 1000 lb across the second valve. In the case of some homogenizers the second-stage effect is provided in the design of the single valve, i.e., without the use of a controllable second valve.

Homogenization also has the effect of making the milk protein less resistant to coagulation. This effect can be demonstrated by adding alcohol to produce coagulation. It is also observed in practice, in the heat coagulation that occurs in the sterilization of evaporated milk. In the case of ice cream the destabilizing effect becomes evident in rare instances in the form of a curdled mix as it flows over the surface cooler after homogenization. More commonly the destabilizing effect does not become evident until the mix has been exposed to the further destabilizing influence exerted by the freezing.

Cooling and aging. When the mix leaves the homogenizer, it is to be cooled immediately to 38 or 40 F. The homogenization causes a temperature rise of several degrees, due to the heat of friction. The exact temperature of the mix depends upon the temperature at which it entered the homogenizer, the pressure employed, and the limited cooling by heat losses from the sanitary piping. Usually the mix is at 150 to 155 F at the start of the cooling. Because of the relatively high viscosity that may be involved in ice cream mixes, plate coolers have not been used. To a limited extent jacketed tubular coolers are in use, but the most common type of cooler for this purpose is the surface cooler. Water is used in the upper section, and refrigerated water, brine, or in some instances direct expansion are used in the lower section.

In figuring the **cooler area** required for a given cooling capacity generous allowance must be made for the fact that the mixes may vary appreciably in viscosity, and in any case rapidly increase in viscosity on cooling. It would be desirable to have accurate **viscosity data** on ice cream mixes for the various temperatures in-

volved in the cooling range. Unfortunately the limited data on this subject are for mixes at the aging temperature of 40 F, and in most cases viscosities were measured after aging. In any case the data would have to be very extensive to take into consideration all of the factors that affect the viscosity such as fat content, total solids content, kind and amount of stabilizer, heat treatment of (part of) the serum solids, and fat clumping. As general information, the **viscosity** at the start of cooling may be 3 to 8 centipoises and at 40 F it may be anywhere from 20 to 300 centipoises, or even higher.

After the mix has been cooled it should be aged at the very least for two hours before frozen into ice cream. Aging improves the whipping ability of the mix and the body and texture of the ice cream made from it. The improvement is most rapid during the early stages of aging, but worthwhile improvement occurs during the first 24 hr. Beyond 24 hr, further holding should be considered merely a matter of storage. For the purpose of aging and storage, well insulated vats or tanks constructed of stainless steel or glass enamelled steel are in common use. For 24-hr holding no supplemental refrigeration is required, but for longer holding, means should be provided for applying such additional refrigeration as is necessary to keep the temperature below 40 or 42 F.

Freezing Procedure

The ice cream freezer has two functions to perform—freezing the mix to the desired consistency, and whipping in the desired amount of air in a finely divided condition. The usual aim is to conduct the freezing and later hardening in such a manner as to obtain the smoothest possible texture. A number of interesting factors are involved in attaining this result.

In freezing an ice cream mix we are freezing a mixed solution. The solutes which determine the freezing point of this solution are the lactose and the soluble salts contained in the serum solids, and the sugars added as sweetening agents. The other constituents of the mix affect the freezing point only indirectly, by displacing water and affecting the in-water concentration of the solutes mentioned. Leighton[1] has developed a reliable method for computing **the freezing points** of ice cream mixes from their known composition. He adds the lactose and sucrose content of the mix, expresses their concentration in terms of parts of sugar per 100 parts of water, and determines the freezing point depression due to the sugars by reference to published data for sucrose. This is justified since lactose and sucrose have the same molecular weight.

$$\%\ \text{lactose in mix} = \%\ \text{serum solids} \times 0.545$$

$$\frac{(\%\ \text{lactose} + \%\ \text{sucrose}) \times 100}{\%\ \text{water in mix}} = \text{parts lactose} + \text{sucrose per 100 parts water}$$

To the freezing point depression caused by these sugars he adds the depression which will be caused by the soluble milk salts. The depression caused by the salts is computed as follows:

$$\text{Freezing point depression caused by serum solids in °C} = \frac{\%\ \text{serum solids} \times 2.37}{\%\ \text{water in the mix}}$$

Table 1 presents the freezing points of various ice creams and a typical sherbet and an ice, as computed by Leighton's method.

The freezing point, of course, merely represents the temperature at which freezing commences. As in the case of all solutions, the unfrozen portion becomes more concentrated as the freezing progresses, and the freezing temperature therefore decreases as the freezing progresses. In a simple solution, containing only one solute, this trend would progress until the unfrozen portion represents a saturated solution of the solute, and thereafter the temperature would remain constant until the freezing had been completed. This temperature is known as the **cryohydric point** of the solute in question. In a mixed solution such as ice cream, containing several sugars and a number of salts, no such point can be recognized. On the contrary the indications are quite definite that the sugars remain in solution in a supersaturated state in the unfrozen portion of the product. This is apparently due to the fact that by the time the saturation point has

Table 1. Freezing Points of Typical Ice Creams, Sherbet, and Ice

Composition of the mix, %					Freezing point, °F
Fat	Serum solids	Sugar	Stabilizer	Water	
8.5	11.5	15	0.4	64.6	27.59
10.5	11.0	15	0.35	63.15	27.57
12.5	10.5	15	0.30	61.7	27.55
14.0	9.5	15	0.28	61.22	27.68
16.0	8.5	15	0.25	60.25	27.79
10.5	8.4	Sucrose, 12; Dextrose, 4	0.40	64.7	27.39
Sherbet—					
1.2	1.0	Sucrose, 22; Dextrose, 8	0.50	67.3	25.97
Ice—					
0	0	Sucrose, 23; Dextrose, 9	0.50	67.5	25.68

been reached, the temperature is so low and the viscosity is so high that we have essentially the glass state. It is interesting to note, however, that in a mixed solution the temperature required for complete freezing must be somewhat below the cryohydric point of that solute which has the lowest cryohydric point. In the case of ice cream, that solute is calcium chloride, contained as a natural component of serum solids. The cryohydric point of calcium chloride is −67 F[2] (see Chapter 6, Basic Volume, 1942). Therefore, we may say that the ice cream ranges from 0 percent frozen to 100 percent frozen between the approximate temperature range of 27.5 to −67 F.

In accordance with the above, the temperature to which the ice cream has been frozen becomes a measure of the degree to which it has been frozen. This is illustrated by **Table 2**, in which the freezing points of the unfrozen portions have been computed when from 0 to 90 percent of the original water have been frozen out as ice. For this purpose the third ice cream of Table 1 has been selected as being most typical of normal operations.

Refrigeration requirements in cooling and freezing. Exact calculation of refrigeration requirements is complicated by the number of factors involved. The specific heat of the mix varies with its composition. According to Zhadan[3] the specific heat of food products may be computed by assuming the following specific heats for the chief components: carbohydrates, 0.34; proteins, 0.37; fats, 0.40; water, 1.00. This does not include salts; where they are present in significant amounts as in ice cream (9.5 percent of the serum solids), a specific heat of 0.20 will be quite accurate. The value given by Zhadan for fats is apparently for solid fats. For butterfat in a liquid condition Hammer and Johnson[4] found the specific heat to be 0.52. In addition their data clearly show that the latent heat of fusion of fats becomes involved. From their data the latent heat of fusion of milk fat or butterfat appears to be about 35 Btu per lb. The change from liquid to solid fat occurs over a wide temperature range, approximately 80 F to 40 F; whereas in changing from solid to liquid fat the range is approximately 50 F to 105 F. This wide discrepancy between solidifying and melting behavior is apparently due to the fact that butter fat, more so than any other fat, is a mixture of glycerides, and mutual solubility of the glycerides is involved. In any case the latent heat of fusion of the fat is involved in cooling the mix from pasteurizing and homogenizing temperature down to the usual aging temperature of 38 to 40 F. Instead of undertaking detailed calculations, based on such considerations as just presented, it is common practice to assume a **specific heat** of 0.80 for ice cream mix; this figure is generous for mixes ranging from 36 to 40 percent total solids.

In calculating the refrigeration required

Table 2. Freezing Behavior of a Typical Ice Cream

Water frozen to ice, %	Freezing point of unfrozen portion, °F	Water frozen to ice, %	Freezing point of unfrozen portion, °F
0	27.55	40	24.40
5	27.35	45	23.63
10	27.05	50	22.62
15	26.78	55	21.42
20	26.40	60	19.79
25	26.04	70	14.99
30	25.70	80	5.14
35	25.03	90	−22.29

Composition: Fat, 12.5; serum solids, 10.5; sugar, 15; stabilizer, 0.30; water, 61.7.

in freezing and hardening, one is hardly justified in speaking of a specific heat for frozen ice cream. As has been shown in connection with Table 2, any change in temperature in freezing and hardening involves some **latent heat** of fusion of the **water,** as well as the **sensible heat** of the **unfrozen mix** and the **ice.** The heat units that become involved as latent heat of fusion per degree temperature change differ according to whether the temperature change is near the initial freezing point or farther along the freezing process. Near the initial freezing point much more latent heat of fusion is involved per degree temperature change than is true in well hardened ice cream, e.g., at −10 F to −11 F. For this reason it is preferable, instead of attempting to use an overall figure in terms of specific heat, to compute as follows:

1. Having in mind the temperature to which the freezing is to be carried, determine, by calculations such as those employed in connection with Table 2, how much water will be converted to ice. Lb of water frozen × 144 = heat to be removed as latent heat of fusion.

2. To compute the sensible heat that must be removed in the desired temperature change, treat the problem as though the product were mix, i.e., use the specific heat for ice cream mix. °F temperature change × lb of product × 0.80 = sensible heat to be removed.

It is true that in such a calculation the water that is present is treated as though it all remained in a liquid form until the desired temperature has been reached, when as a matter of fact ice was forming progressively. Insofar as ice has a specific heat of 0.492 instead of 1.0 as for water, this treatment will err in the direction of generous refrigeration. To offset this there is the fact that in the freezer vigorous agitation is employed, which develops heat of friction. It has been estimated that approximately 80 percent of the energy input in the motor of the freezer is converted to heat in the product. Where the product is frozen to a stiff consistency and power requirements have thereby been increased, an additional allowance should be made for this factor, even though the discrepancy of the above calculation is involved.

Since **capacities** in the case of ice cream are customarily figured in terms of gallons, it becomes necessary to convert gallons to pounds of product. The weight of a gallon of ice cream mix ranges from 9.0 lb for mixes with a high fat content to 9.2 lb for mixes with a low fat content, and a high content of serum solids and sugar. The weight of a gallon of ice cream varies with the mix weight and overrun. The relationship between weights and overrun is as follows:

$$\text{Percentage overrun} = 100 \times \frac{\text{Wt per gal of mix} - \text{Wt per gal of ice cream}}{\text{Wt per gal of ice cream}}$$

(For the purpose of calculating overrun any unit of volume can be used provided that same unit is used throughout.)

Obtaining a smooth texture. To obtain a finished product with a smooth texture, the ice crystals must be small and the air cells finely divided. To some extent these two properties are interdependent. In crystallization in general, to obtain small crystals the crystallization should occur rapidly, preferably with agitation, and with liberal "seeding." In the freezer all three of these requirements are met. The **rate of crystallization** in the freezer is far more rapid than later in the hardening process. In the freezer agitation is provided as against no agitation during hardening. In the freezer a "seeding" is produced by the process of freezing the film of mix adjacent to the freezer wall, and scraping it off by the scraper blades. The seeding may be by

numerous fine ice particles or fewer coarse particles according to the efficiency of this scraping process. To have efficient scraping the blades must be sharp, must make the proper angle of contact and must make actual contact with all of the freezing area.

Since the conditions are far more ideal in the freezer than in the hardening process, the aim should be to accomplish as much of the freezing as possible in the freezer. There will then be correspondingly less water to be converted into ice in the hardening process, and there will be more ice crystals onto which the additional ice can build.

While conditions are less ideal in the hardening process than in the freezer, the rate of crystallization is still of decided importance. In slow hardening the tendency is to deposit the ice onto crystals already in existence, while in rapid hardening new crystals will form, and the texture will be definitely smoother.

Freezing by batch freezers. In batch freezers, ranging in capacity from 10 to 160 quarts, enough mix and flavoring material are placed in the freezer to fill it to slightly less than half of its actual capacity, thus allowing room for whipping. With the scraper and dasher mechanism in motion, refrigeration is applied by circulating brine at −10 F through the jacket of the freezer, or by opening the suction valve in flooded-system, direct-expansion freezers. The suction pressure is regulated to be equivalent to a temperature of −10 to −15 F. Freezing is allowed to continue until the desired consistency has been reached; the refrigeration is then turned off, anticipating this point as necessary in cases where the additional refrigeration, trapped in the freezer jacket, is too great. The whipping is allowed to continue until the desired overrun has been obtained, as determined by withdrawing a special cupful and weighing. During this whipping stage the temperature will go up slightly due to the heat of friction, as well as to imperfect insulation. If the mix is too slow in whipping, this temperature rise will ultimately make successful attainment of the desired overrun impossible. Not only the temperature rise but also the churning, which will inevitably occur to some degree, is detrimental to whipping capacity.

In a batch freezer the consistency to which the ice cream may be frozen is limited by two considerations: (1) When the desired overrun has been reached, it must be possible to empty the freezer with reasonable speed; and (2) the optimum consistency from the standpoint of whipping will be passed and it may be impossible to attain the desired overrun. For this reason the whipping ability of mixes is important; if the whipping ability is high, it is possible to freeze to the maximum stiffness permitted by the former consideration without sacrificing overrun. A drawing temperature of 24 F is about as low as can be successfully achieved in batch freezers.

Freezing by continuous freezers. In the use of continuous freezers the mix and air in controlled proportions are pumped through the freezing chamber under positive pressure. The first limiting consideration of batch freezers is eliminated by virtue of the continuous stream and the positive pressure to propel the stiffer ice cream. The second consideration is overcome by virtue of the fact that the whipping proceeds under pressure. The air is in a compressed state, and in the freezing chamber where the agitation is vigorous the mix is not required to take a high overrun, and under the comparatively gentle agitation incidental to the discharge flow and expansion to atmospheric pressure, the air remains incorporated. According to the make of the freezer and operating conditions the pressure under which the freezing and whipping occur ranges from 30 to 100 lb per sq in. Under these conditions it is possible to freeze the ice cream to a stiff consistency so that it holds its shape with little tendency to flow. The usual drawing temperature is 21 F and in some instances slightly lower. From Table 2 it is evident that this operation converts appreciably more of the water into ice than is the case with batch freezers. The texture of the finished product is definitely smoother.

In adding flavoring materials such as fruits, where the aim is to keep the pieces more or less intact, the addition is made just before the product is to be drawn from the freezer in batch operations. There is no

comparable opportunity for late additions in the case of continuous freezers. This problem is overcome by the use of fruit feeders which inject the cooled flavoring material in controlled amounts into the discharge pipe at any convenient point; for example, into the pipe taking the discharged product from several freezers.

In any case, whether continuous or batch operations are used, the ice cream should be placed in the hardening room as promptly as possible. Any partial melting is detrimental to the texture. The water that forms on melting is more free than the water that has never been frozen, and on refreezing will form larger ice crystals.

Hardening Ice Cream

The hardening is accomplished by placing the filled containers of ice cream in a hardening room where the temperature is below 0 F, preferably at −10 to −15 F. The **still-air type** of hardening room, in which most of the expansion coils serve as shelving, is probably still the most prevalent type. The gravity-air type of hardening room is not very widely used. In recent years the trend has been towards **forced-air types** of hardening rooms.

The advent of the continuous freezers had a decided effect in promoting this trend. When the first modern continuous freezer was introduced, at least one chain of ice cream plants changed practically all of their operations to continuous freezers and, in their advertising program, featured the smoother texture of their product. Other manufacturers who were unwilling to discard all of their batch freezers as obsolete, continued to use them and sought the smoother texture by quick hardening, by passing the ice cream through hardening tunnels where the ice cream packages were exposed to rapidly circulating air at temperatures of −30 to −50 F. The general introduction of continuous freezers has curbed further developments employing such extreme temperatures. Another factor has been the indication that such extreme hardening tends to cause shrinkage when the ice cream is later distributed under normal conditions.

Movement of the air in the hardening room hastens hardening.[8] In a still-air room at −6 to −20 F the center of a 5-gal can showed no temperature drop in 5 hr and required 13 hr to reach 0 F. Circulating the air by means of an electric fan (conditions not accurately specified) reduced the hardening time to about one-half. Observations were also made on such factors as drawing temperature, freezing point of the mix, and the type of material used for packaging. Drawing the ice cream 2.5 F colder from the freezer reduced the hardening time about 16 percent. This coincides quite well with what might be expected from Table 2 (compare the temperatures of 25 and 40 percent frozen ice cream). A higher mix freezing point shortened the hardening time, since for a given drawing temperature such a product will be more completely frozen. A black surface on the packages reduced hardening time 15 percent. Fiber cans caused more rapid hardening than paper cans and tinned steel cans hardened most slowly in still air.

The preferred type of forced-air hardening room is one in which the refrigerating surfaces are in the form of a compact unit, housed and connected with the hardening room in such a manner that the air ducts to and from the room can be closed conveniently for defrosting. **Defrosting** is then done by shutting off the refrigerant and circulating air from a warm room or from the outside over the refrigerating unit. In this manner, the accumulated frost can be removed in a matter of minutes, and the entire operation is so convenient that defrosting can be done daily and the refrigerating surface can be in almost ideal condition at all times.

A further extension of this system would be to partition the hardening room into cabinets along each side of a central aisle with flues to admit air at the bottom and collect it for return at the top of each cabinet. By controllable vents or registers, the flow of air could then be directed where it is most needed, e.g., to freshly frozen ice cream. Such confinement of the air would also be advantageous in reducing cold air losses and warm air entrance with each opening of the hardening room door. As far as the writer is aware no such installations have as yet been made.

Transportation

For **retail delivery** of ice cream, single-service, insulated cartons (corrugated paper type) and single-service containers are now generally used with frozen carbon dioxide in amounts adjusted to the holding requirements. For express shipments single service packers may be employed, but more commonly more substantial insulated packing cases are used and returned for repeated deliveries. Frozen carbon dioxide is the refrigerant most commonly used, although in some cases frozen brine cartridges are still employed.

For delivery of ice cream to dealers, enclosed **trucks** with well insulated bodies are now used almost universally. Frozen brine cartridges and frozen carbon dioxide have been used, but the most common type of truck body now is one equipped with a large flat brine cartridge across the entire body ceiling with an expansion coil imbedded in the brine. At the home plant, the truck is refrigerated and the brine is frozen by connecting the expansion coil to the plant refrigerating unit, pumping the coil empty before disconnecting just before the truck leaves on its trip. The brine for this purpose, as for any of the brine cartridges here mentioned, must be made up of a salt which has a cryohydric point that coincides, or nearly coincides, with the temperature desired. Since the temperature desired for this purpose is approximately −5 F, the salt is common salt with a brine concentration that represents the cryohydric mixture. In the case of some large trucks, delivering over a considerable distance and time, the truck body is refrigerated by a small compressor driven by a power take-off from the truck motor or by a small independent gasoline engine.

Retailing

Electric cabinets with thermostatically controlled compressors are now in almost universal use. A few brine cartridge cabinets may still be in service. The temperature desired in retail cabinets is about 5 F. It varies somewhat with ideas as to the proper serving consistency and with the freezing characteristics of the product. For average ice cream 8 F gives a fairly soft serving consistency.

If the ice cream or other frozen dessert has a high sugar content, or a high content of low molecular weight sugars (dextrose, levulose, or invert sugar), its freezing point is lower and its entire freezing curve, comparable to Table 2, is lower. A small difference in freezing point becomes appreciably wider in terms of the temperature required to produce a comparable cabinet consistency.

Constancy in temperature is desirable in retail cabinets, but under the conditions of normal use is difficult to achieve. As far as effect on texture is concerned, temperature variations at the retail cabinet are far more damaging than in the usual hardening room. Temperature variations cause a coarsening in texture in any case, because with each rise and fall in temperature there is some melting and refreezing. On any melting, larger crystals will remain, and on refreezing, the tendency is to build onto the crystals that are already there. Retail cabinets are most damaging, first of all because temperature fluctuations are numerous and because for a given rise and fall in temperature (e.g., 1 F) there is appreciably more water involved than is true at the usual temperature level of hardening rooms. For this reason rapid turnover in retail cabinets is desirable. Ice cream stabilizers are used as a mix ingredient to limit this effect but in no case can they eliminate it entirely. The few manufacturers who choose to make ice cream without a stabilizer in order to capitalize on this fact in their sales policy must, of necessity, operate so as to achieve very rapid turnover.

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If you searched this chapter for something which was not found in it, please let the editors know.

5. FREEZING OF MEATS

REFRIGERATION, particularly at temperatures below the freezing point of water, may be considered one of the fundamental methods of preserving meats. Other important methods are curing, heat sterilization and dehydration. Meat may be preserved for months by freezing and freezer storage without significant change, whereas preservation by any of the other methods involves characteristic changes in the appearance, flavor and texture of the meat. Therefore, as a means of preserving the original characteristics of fresh meat, freezing has no equal. Freezing as a means of preservation, however, is not a foolproof procedure, as there are many factors both ante-mortem and post-mortem which affect the quality of frozen meats. This paper will be confined to a discussion of the various operations as they relate to quality in frozen meat.

Preparation

Under commercial operating conditions, cattle are slaughtered, skinned, eviscerated, washed, clothed and moved to the chilling cooler in approximately one hour. In the case of hogs, lambs and calves, the time required for the dressing operation is less than one hour. It is important that these operations be performed quickly, thereby reducing the exposure of the carcass to temperatures which are conducive to bacterial activity and color deterioration.

In prewar years it was standard practice for processors to grade and brand the beef, lamb and veal carcasses. In addition, a considerable number of carcasses were graded by the U. S. Department of Agriculture. As a wartime measure, all beef, lamb and veal carcasses are graded according to U. S. government standards. In cases where U.S.D.A. graders are not available, arrangements are made whereby the operator grades the meat according to U. S. government specifications. The chilled beef, lamb, and veal carcasses are graded into the following categories:

Beef—choice, good, commercial, utility, cutter and canner.

Lamb and veal—choice, good, commercial, utility, and cull.

Ordinarily the carcasses are cut into wholesale, retail or boneless cuts before freezing, but beef quarters, pork sides, lamb and veal carcasses are sometimes frozen. Reference is made to meat charts prepared by the National Livestock and Meat Board[4] which show dozens of retail cuts of fresh beef, lamb, veal and pork. All these cuts may be successfully frozen.

The practicability of freezing boneless meats has been proved by the army quartermaster program. Millions of pounds of boneless beef have been frozen and transported overseas in the frozen state with satisfactory results.

Aging or Ripening

It is desirable to age some cuts of beef before they are frozen. For the most part, only those cuts which are used for steaks and dry roasts are aged for long periods. The purpose in aging meat is primarily to improve tenderness, although if continued for a month or more there is a modification in the flavor of the meat.

In commercial practice, beef is aged about three weeks under controlled air conditions wherein the temperature is between 32 and 36 F, the relative humidity between 86 and 92 percent, and the air movement 20 to 60 ft per min over the product. Extensive experiments have shown

JOHN M. RAMSBOTTOM, Author Chapter 5. Born 9/1/02 at Lanark, Ontario, Canada. Educated at Univ. of Toronto, BS, 1929; Iowa State, MS, 1931; PhD, 1933.

Formerly Asst. Iowa State College, 1933–35; Research Chemist, Swift and Co., 1935 to date.

Author of numerous articles in chemical and trade journals on the chemistry, nutrition and technology of meat products with especial emphasis on the technology of frozen meats; Chap. 5, 1946 Applns. Vol., ASRE Data Books. Member of Amer. Chemical Society; Amer. Soc. Animal Production; Inst. Food Technologists; Amer. Society of Refrig. Engrs. At present he is Head, Packaging Research Division, Research Laboratories, Swift and Co., Chicago, Ill.

that approximately 90 percent of the improvement in tenderness takes place during the first 10 to 12 days of storage. Some beef processors speed up the aging process by raising the temperature of the meat to 45 to 60 F for two or more days under controlled conditions of relative humidity and air movement and in the presence of ultra violet light. Increasing the temperature in the meat accelerates the activity of the autolytic enzymes, thereby increasing the rate of hydrolysis or breakdown of the tough tissues in the meat. This beneficial effect is not without its disadvantages, as the color, bloom and keeping quality are adversely affected by exposing the meat to temperatures above the cooler range.

Aging periods in excess of 10 or 12 days before freezing are not recommended. This is primarily because the storage life of meat decreases as the aging period increases. The freezing process in itself is reported to have a tenderizing effect on meats.[11]

Packaging

In commercial practice, most meats are packaged before freezing. The package serves as a protection against (1) surface desiccation or "freezer burn," (2) discoloration and loss of bloom, (3) shrinkage, (4) contamination, (5) chemical changes, (6) freezing of individual units into a mass if piled together. The package may also serve to form boneless meats into units which make for maximum utilization of storage or shipping space and ease in handling.

The requirements of a good packaging material for frozen meats are listed as follows:

1. Low moisture vapor transmission
2. Highly resistant to the passage of air, water and fats
3. Not easily stained
4. Flavorless and odorless
5. Highly resistant to tearing and breaking
6. Flexible and stretchable at temperatures above and below the freezing point
7. Transparent, if the product is to be marketed in the package. Transparency serves no purpose if the product has to be thawed and processed before marketing.

Different types of packaging material are used, including many kinds of paper which are treated with wax or some other moisture-vapor resistant material. Moisture-vapor resistant cellulose has been used extensively for packaging frozen meats. There is a growing interest in pliofilm, rubber latex bags, metal foils, and laminated films as packaging materials for frozen meats. Waxed cardboard cartons with or without liners are extensively used for packaging boneless meats for freezing. These full-telescope-style cartons ordinarily hold 50 to 100 lb of meat. The meat cuts may be wrapped separately in waxed paper before being packaged in the carton. The cartons are designed so that they have a large area in proportion to depth, consequently the product in the center of the package will freeze in a shorter time than if the package were cube shaped.

In the past, tin pails of 10-lb capacity were standard containers for items like lamb and veal livers. Because of the current shortage of tin, waxed or lacquered paper-board pails are also used.

Frozen meats for the retail trade are packaged in transparent materials, paperboard cartons, etc. If the carton does not permit display of the product, then the description and advertising of the product is printed on the carton or on the overwrap. Frozen meats have been successfully merchandised in both "blind" and transparent types of packages.

Moisture-vapor-proof wrapping materials should be kept in actual contact with the product, for best results. If there are air pockets between the packaging material and the meat, the rate of freezing at that location is delayed. Furthermore, during freezing and storage, moisture from the surface tissues is transferred to the inner surface of the packaging material, where it is deposited in the form of ice crystals. It is important that the packaging material be completely sealed, as there is nothing to be gained by using a moisture-vapor-proof packaging material if moisture vapor may be lost from the package by improper sealing.

Methods of Freezing

The systems now used commercially for the freezing of meats may be conveniently classified into five groups.

1. Still air. Freezing in still air is one of the oldest methods used for meats and other food products. According to best practice, the product is packaged and spaced on racks in the freezer so that the air may circulate by natural movement between the packages. A freezer temperature of −10 F or lower is recommended. When the product is frozen, the racks are removed and the product is re-piled to conserve space. The method is often referred to as "sharp" freezing as differentiated from "quick" freezing.

2. Air blast. Air-blast freezing at temperatures of −10 to −40 F and air speeds of 500 to 1500 ft per min is used extensively for meats. The air blast may be directed on products piled according to the method recommended in still-air freezing, or the air blast may be localized in a tunnel equipped with either a conveyor or open-shelf trucks which hold the product during the freezing operation.

In air-blast freezing it is important that the temperature of the recirculated air be kept as low as is practical, not only to accelerate the rate of freezing, but, more importantly, to reduce the desiccation of, or moisture loss from, the product. For example, air at −10 F has approximately five times more moisture carrying capacity than air at −40 F. Consequently, the desiccating effect of air at −10 F is much greater than that of air at −40 F.

The direct addition of moisture to the air in the tunnel may be used to raise the relative humidity in the tunnel. This is not very satisfactory, however, as the added moisture quickly freezes on the refrigerating coils and lowers their efficiency.

The Finnegan multi-stage tubular freezer[9] reduces the desiccating effect in air-blast freezing by freezing the product in a number of stages of successively lower temperatures. By this method the temperature differential between the coil and product is low, with consequent reduction in desiccating effect on the product.

The advantages of air-blast freezing over freezing in still air are (1) a faster turnover of product with resulting economies in time and space; while the cost of refrigeration per ton will be higher, the total tonnage required may be less; (2) a more quickly frozen product which is desirable from the standpoint of quality and appearance.

3. Indirect contact. The Birdseye multi-plate freezer[20] is an example of indirect contact freezing. This freezer consists of a cabinet equipped with refrigerated hollow metal plates, placed one above the other in such a way that they can be moved apart to receive packaged products and then closed upon the product with any desired pressure. The plates are made of aluminum alloy with internal passages for the circulation of the refrigerant. The freezing is done by the direct expansion of ammonia or by brine.

4. Air-blast and indirect-contact freezing. There are a number of methods wherein combinations of air-blast freezing and indirect-contact freezing are used. The most common method is simply to arrange the cooling coils as shelves, and pile the packaged product on the shelves. Blowers are often used to circulate the air over the product and coils. In this way products are frozen by conduction from the underside and by convection from the upper side.

5. Refrigerated liquid or spray. A number of methods have been developed wherein meats have been packed in moisture-proof containers and frozen by immersion in refrigerated brine or other liquids. In the Z-process the freezing is done by the application of a fog or spray of low temperature salt brine or other liquid having a low freezing point.[20]

Quick Freezing vs. Slow Freezing

Stiles[25] states that the factors affecting the **time of cooling** may be grouped into two classes: internal factors depending on the nature of the cooled substance, and external factors depending on the properties of the external medium. The former include thermal conductivity, specific heat, latent heat, specific surface, and nature of surface of the cooled body; the latter include the temperature, conductivity, spe-

cific heat, density, and degree of agitation of the external medium.

At any given freezing temperature there are a number of factors which affect the rate of freezing of meat. It is increased by (1) using methods which accelerate the transfer of heat, (2) using packaging materials which have low insulating value, (3) preventing air pockets within the package, (4) reducing the size or thickness of the cut.

According to Moran[18] meat is quick frozen if it is chilled through the temperature range of 41 to 23 F in ½ hr or less. Poole[19] states that meat is quick frozen if it is chilled through the temperature range 31 to 25 F in 25 min and he describes this temperature range as the zone of maximum ice-crystal formation. The size and location of ice crystals in the frozen meat depend on the rate at which the temperature of the meat is dropped from just above the freezing point (29.5 to 30 F for beef) to a temperature of approximately 25 F. The ice-crystal pattern is decided by the rate at which the meat is chilled to 25 F; however, the temperature of the meat must be reduced to 0 F or lower for satisfactory storage results. If the temperature of the meat is dropped through the zone 31 to 25 F quickly, the ice crystals will be smaller than if its temperature is reduced slowly.

Fig. 1 shows that when steaks are frozen at −33 F in an air blast of 1400 ft per min, the temperature drops through the zone of maximum crystal formation in 10 min. When similar steaks are frozen in still air at −25, −10, 0, +10 and +20 F, the time required for the temperature to drop through this zone increases progressively to 7 hr.

The relationship between the size and location of ice crystals and the temperature of freezing is illustrated in **Figs. 2, 3** and **4.**

It will be observed that when steaks are frozen at −30 F, intrafiber freezing takes place. The water is frozen within the fibers as single columns of ice (Fig. 2), the fiber protoplasm being located at the margin of the ice columns. When the steaks are frozen at −10 F (Fig. 3), the tissue fluid that freezes at this temperature is frozen external to the fibers, which may be termed extrafiber freezing. When beefsteaks are frozen at +20 F (Fig. 4), the ice formations are located outside the fibers and are fewer and larger than those occurring in the muscle tissue frozen at −10 F. The fiber bundles are forced into ridge-like formations which are characteristic of slowly frozen meats.[21]

In addition to the effect that the rate of freezing has on the size of the ice crystals, the length of time between slaughter and freezing is important.[22] **Figs. 5, 6,** and **7** show the microscopic appearance of ice crystals in steaks frozen at −30 F at ¼, 1, and 35 days after slaughter respectively. The ice crystals are progressively larger as the time between slaughter and freezing is increased. This phenomenon is attributed to the physico-chemical changes which take place in the muscles during and following rigor mortis.

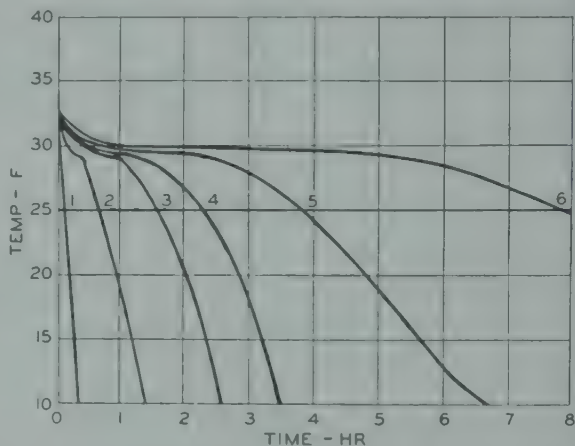

Fig. 1. Curves Showing Rate of Freezing of Beef Steaks One Inch in Thickness.

1. −33 F in air blast of 1400 ft per min
2. −25 F in still air
3. −10 F in still air
4. 0 F in still air
5. +10 F in still air
6. +20 F in still air.

It is practically impossible to obtain a uniform rate of quick freezing if the unit of meat is large. This is illustrated in **Fig. 8.** When a beef round was frozen at −32 F in an air blast of 1400 ft per min, the temperature of the muscle tissue ½ in. from the surface dropped from 34 to 25 F in ½ hr. In the center of the round, 8 hr were required for the temperature to fall through the same range.

The quickly frozen superficial tissues

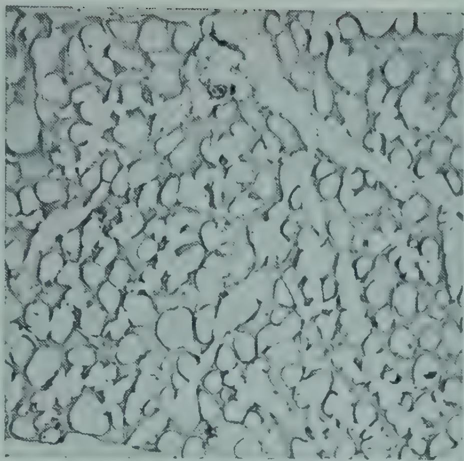

Fig. 2. Microscopic Appearance of Ice Crystals in Steaks Frozen at −30 F Air Blast (×63).

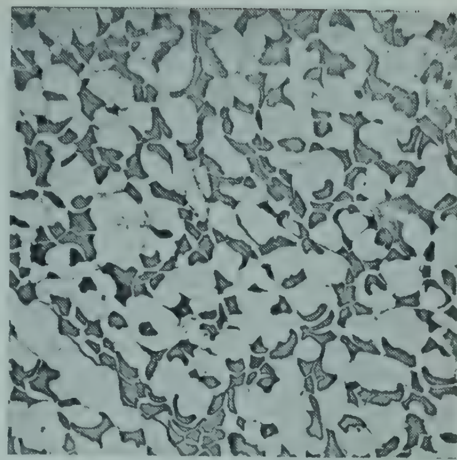

Fig. 3. Microscopic Appearance of Ice Crystals in Steaks Frozen at −10 F Still Air (×63).

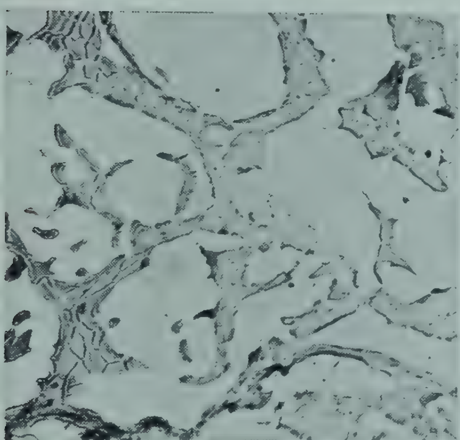

Fig. 4. Microscopic Appearance of Ice Crystals in Steaks Frozen at +20 F in Still Air (×63).

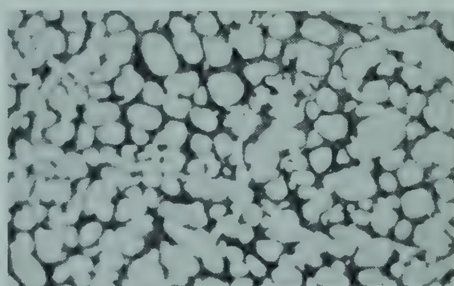

Fig. 5. Microscopic Appearance of Ice Crystals in Steaks Frozen at −30 F in Still Air 6 hr After Slaughter (×63).

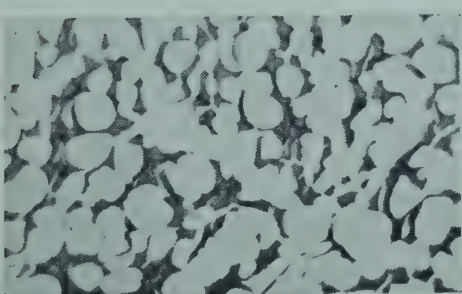

Fig. 6. Microscopic Appearance of Ice Crystals in Steaks Frozen at −30 F in Still Air One Day After Slaughter (×63).

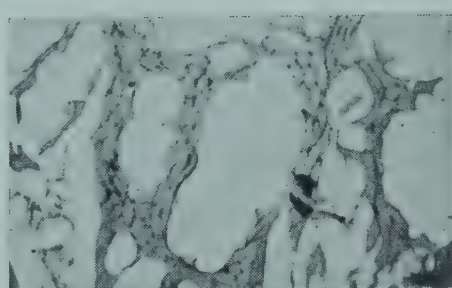

Fig. 7. Microscopic Appearance of Ice Crystals in Steaks Frozen at −30 F in Still Air 35 Days After Slaughter (×63).

were light red in color, most of the light being reflected by the small intrafiber ice crystals. Conversely, the slowly frozen meat in the center of the round was dark red in color, more of the light being absorbed by large ice crystals. As indicated by these data, there is a rate of freezing lean meat which produces a color approaching that of unfrozen lean meat.

Moran[17] has made measurements of the amounts of ice present in beef, lamb and pork muscle when frozen to equilibrium at different temperatures. The results were similar for all three kinds of meat. The total water in each muscle was determined by drying a similar sample at 217.4 F for one week. The amounts of ice formed in the muscles at the different temperatures were tabulated (Table 1).

Table 1. Ice Formed in Beef, Lamb and Pork Muscles

Equilibrium temperature, °F	Increase in vol per 1 g. water in muscle, cc	Sp vol of supercooled water, cc	Sp vol of ice, cc	Water frozen, %
29.3	0.0320	1.00027	1.09049	35.5
28.4	0.0500	1.00032	1.09041	55.5
26.6	0.0627	1.00043	1.09024	69.8
23.0	0.0727	1.00076	1.08990	81.6
19.4	0.0784	1.00118	1.08956	88.7
14.0	0.0819	1.00196	1.08905	94.0
−4.0	0.0821	1.00379	1.08735	98.2

Freezer Storage Conditions

The quality of frozen meat is materially influenced by storage conditions. It is important that the storage temperature be as low as is economically feasible. The relative humidity in the freezer storage rooms should be kept at as high a level as is practical and air circulation should be limited to that necessary to maintain a uniform temperature at all locations in the storage room.

Temperature. The storage life of meat depends to a large extent on the temperature of freezer storage. While there is little agreement among investigators as to how long meats may be stored and still be of top quality, it is universally agreed that when meats are to be stored for prolonged periods, the temperature should not be above 0 F.

Meats which have been prepared according to good commercial technique may be stored at 0 F for at least 3 to 4 months and yet will be comparable in quality to the original unfrozen product.[8,27] Many investigators report good results after storage periods of 8 months or 12 months at 0 F.[7,8,13,24] It has been demonstrated that storage temperatures of −10 F, −20 F and −30 F are progressively more effective than 0 F in retaining the quality of fresh meats.[7,23] Consequently, the limiting factor is cost of the additional refrigeration necessary to maintain the lower storage temperatures. A freezer storage temperature of −10 F has become fairly common in the cold storage industry and the trend is toward still lower storage temperatures.

Humidity. The need of moisture-vapor-proof packages would be less urgent if the relative humidity of the air in freezer storage rooms were maintained at a high level.

The cooling coils in a storage freezer are ordinarily 10 to 20 F below the air temperature in the room. This temperature difference depends upon a number of factors, including the ratio of refrigerating coil area to room volume, the amount of frost on the coils and the refrigeration

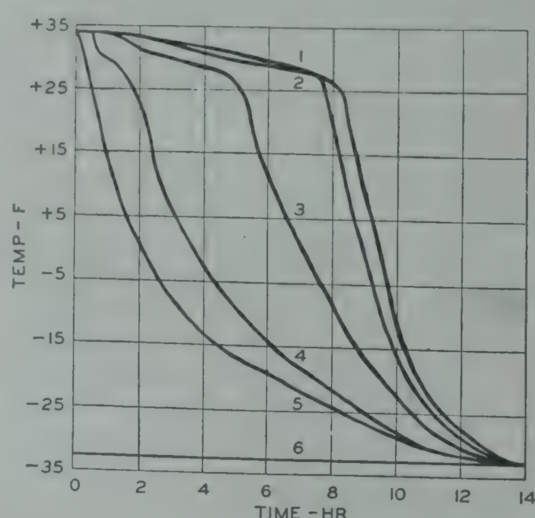

Fig. 8. Freezing Curves for Beef Round. Thermo-couple Depth (1) at Bone Juncture; (2) 4 in.; (3) 2 in.; (4) 1 in.; (5) ½ in.; (6) Room Temperature.

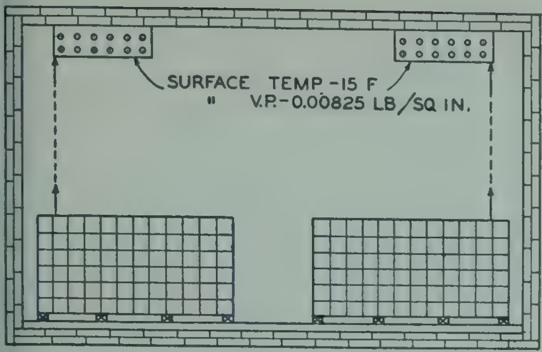

Fig. 9. Moisture Transfer from Product to Cooling Coils During Freezer Storage.

Room Air	*Air Within Package*
Temperature, 0 F	Temperature, 0 F
Vapor pressure, 0.0141 lb/sq in.	Vapor pressure, 0.0188 lb/sq in.
Dew point, −5.2 F	Dew point, 0 F
Relative humidity, 75 per cent	Relative humidity, 100 per cent
Moisture, 0.361 gr/cu ft	Moisture, 0.481 gr/cu ft

losses from the room. Consequently, the coils will condense moisture out of the air until the dew point temperature of the air is approximately that of the coils. On the basis of a 10-degree differential, the relative humidity should reach equilibrium at about 58 to 60 percent. Actual figures on empty freezer storage rooms at 0 F covered the range 60 to 70 percent.

Tests made in commercial freezers held at 0 F and containing varying amounts of packaged meats resulted in relative humidity values of 70 to 80 percent unless special arrangements were made to raise the humidity in the storage rooms. This means that the relative humidity in the freezer is held above 60 percent by evaporation of moisture from the product. The moisture vapor pressure within the package and in contact with frozen food approaches saturation. At 0 F a cubic foot of saturated air has 0.481 grains of moisture which exerts a vapor pressure of 0.0188 lb per sq in., whereas the air of the freezer having a relative humidity of 75 percent contains 0.361 grains of moisture per cu ft, which exerts a vapor pressure of 0.0141 lb per sq in.

The cooling coils at −15 F freeze moisture out of the air onto the coils, and under these conditions the moisture vapor pressure at the coil is 0.00825 lb per sq in. Consequently, because of these differences in vapor pressure, the moisture travels from the air surrounding the product to the air of the room and thence to the cooling coils, where it is deposited as frost **(Fig. 9)**.

As the deposit of frost builds up on the cooling coils, their efficiency is impaired so that periodically they must be scraped or defrosted by recirculation of hot gas or other means.

If the relative humidity in the freezer storage room is kept at a high level, then the vapor-pressure difference between the air in the package and the room air will be small, as will the moisture loss from the product.

Cook[6] reported experiments wherein a relative humidity of 95 percent was maintained in freezer storage by the continuous addition of adequate quantities of water vapor to the atmosphere under conditions which prevented the formation of ice on the cooling coils. These conditions were met by spraying a sufficiently concentrated liquid (soluble salts or ethylene glycol) over the coils to prevent ice formation, evaporating a portion of the water from this liquid and continuously returning the resultant steam to the freezer.

Moisture vapor may be added to the air of the storage room. The relative humidity may be maintained at a high level by this method. However, the cooling coils must be scraped frequently as the added moisture is continuously collecting on the coils.

The simplest method of maintaining high humidity is by increasing the cooling surface and lowering the temperature differential between the refrigerant and room, which in turn raises the relative humidity. For instance, the amount of direct expansion ammonia coil may be increased above the widely used ratio of 1 lin ft of 2-in. coil per 6 cu ft of storage space. Obviously, if the refrigeration losses, through the walls, ceiling, floor and doors of the storage freezer, are kept at minimum by thorough insulation, the temperature differential between the cooling coils and room air will be minimized.

Air circulation. Rapid air circulation, which is an essential feature in some methods of freezing, must be avoided in the

freezer storage of meats. Once the temperature of the frozen product has been dropped to the temperature of the storage rooms, the refrigerated air need only maintain the storage room and product at the desired temperature. Then even limited air circulation between the packages is not desirable since it promotes moisture transfer to the coils. This means that the product should be re-piled as tightly together as is practical.

If the temperature of the product placed in storage has not been dropped to the temperature at which the product is to be stored, then additional refrigeration is required, which means that the product should be piled so as to permit natural air circulation between the packages.

Regardless of the location of the cooling coils or unit cooler in the storage room, natural air circulation must be provided along the floor, walls, and ceiling of the room. It is common practice to pile the product on racks 4 in. above the floor. The space between product and walls and ceiling should be 12 in. and 18 in. respectively.

Deterioration of Product

Undesirable chemical, physical, and biological changes which are associated with poor meat-storage conditions include: (1) Development of rancidity in the surface fatty tissues, (2) desiccation of surface tissues or "freezer burn" with consequent effect on color, bloom, shrinkage, and quality, (3) discoloration caused by ice crystal growth in surface tissues, (4) discoloration caused by oxidation of the hemoglobin in surface tissues, (5) deterioration by microbiological activity.

Rancidity. The most important limiting factor in the storage life of meats is the stability of the fat. Pork fat is much less stable than beef fat, consequently the storage life of pork is less than that of beef. The stability of fat is characterized by an induction period, during the course of which oxidation proceeds rather slowly. At the conclusion of the induction period, oxidation proceeds rapidly. Chemical methods of determining keeping quality of fats usually concern themselves with the length of this induction period. For instance, the Swift stability test[14] measures the amount of oxidation by the time required for a fat to reach a given peroxide level. In addition to chemical tests, fat stability may be measured in flavor tests by the detection of rancidity.

The importance of fat stability in freezer storage of meats is well illustrated by a palatability test on lamb leg and shoulder roasts which had been stored for 10 yr at 0 F for experimental purposes. It was observed that the superficial and deep fatty tissues and muscles containing a high proportion of fat were inedible because of rancidity. The very lean muscles were quite palatable, although not so desirable as a fresh lamb roast.

Desiccation. The loss of moisture from the surface tissues of meats in freezer storage to a stage where they contain from 10 to 15 percent moisture is designated by the frozen meat trade as **"freezer burn"** or desiccation.

Lean tissues which are freezer burned are dry, tough, and lacking in flavor, even after they have been cooked. This indicates that the proteins of freezer-burned tissues have been altered by the dehydration and that the aromatic substances which contribute to aroma and flavor have been dissipated. Freezer-burned subcutaneous tissues are a lifeless light cream to light grey in color. Replacement of the water in the superficial tissues by air appears to hasten the onset of fat rancidity. This is indicated by flavor tests and by the higher initial peroxide values of fat from desiccated superficial tissues as compared to the values for fat from superficial tissues which are free from desiccation.

Discoloration. The red color of lean meat is due to the presence of a colored compound, myohemoglobin, in the muscle tissue. This compound is an integral part of the muscle tissues and should not be confused with hemoglobin, the coloring compound of blood. Myohemoglobin as it occurs in the unfrozen muscle has a deep purple color, and in this state it is known as reduced or unoxygenated myohemoglobin. On exposure to air, a chemical reaction takes place between the reduced myohemoglobin and the air with the formation of oxygenated myohemoglobin, which is bright red in color. This reaction

accounts for the change in the color of unfrozen meat directly after cutting.

Discoloration of the superficial tissues of frozen lean meat during storage may be caused by ice crystal growth or by oxidation of the myohemoglobin to methemoglobin. The first type of discoloration disappears when the meat is thawed. The second form of discoloration remains after the meat is thawed, but has no effect on the color of the cooked meat.

Experimental evidence[23] indicates that under average storage conditions there is little ice-crystal growth in frozen beef. However, when the product is stored at a temperature just below the freezing point,[18] there is a significant growth of ice crystals and consequent darker color.

Representative absorption spectra curves for steaks stored at +10 and −30 F are shown in **Fig. 10.** Curve I, which is quite similar to that of methemoglobin[26] is typical of steaks stored at +10 F for one year.[23] Curve II indicates a mixture of oxymyohemoglobin and methemoglobin and is typical of steaks stored at −30 F for one year. Calculations showed that the amount of methemoglobin in the surface tissues of the steaks stored at −30 F was between 40 and 50 percent of the total pigment present, as compared to between 80 and 90 percent methemoglobin in the surface tissues of steaks stored at +10 F for one year.[23]

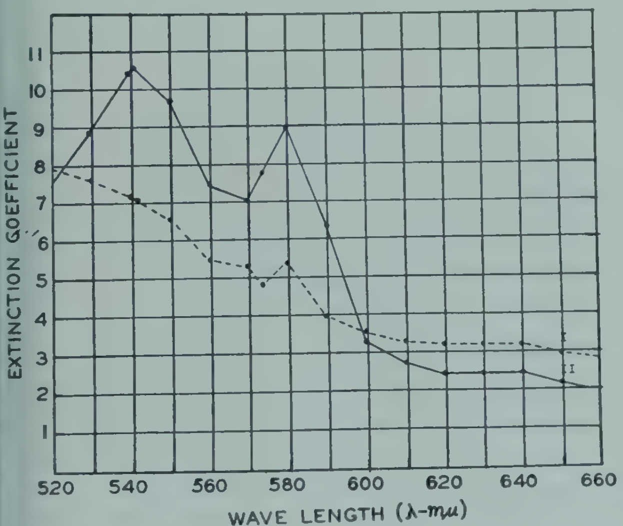

Fig. 10. Absorption Spectra of Extracted Muscle Pigments.

I. Curve for steaks stored for one year at +10 F
II. Curve for steaks stored for one year at −30 F

Microbiological changes. Microbiological activity on the surface and within frozen meat ceases at temperatures of 0 F or lower. At higher temperatures (above 14 F) yeasts and molds will develop, causing deterioration in color, bloom, and keeping quality.[10]

While bacteria are inactivated by low temperatures, Jensen[12] reports that the actual destruction of bacteria in frozen beef and pork is greatest when these meats are stored between 20 and 25 F rather than at much lower temperatures, as might be expected. Unfortunately, because discoloration and rancidity are associated with storage temperatures of 20 to 25 F, it is not considered good practice to utilize this phenomenon.

Autolytic enzymes, particularly lipases and esterases, are active below the freezing point of meat.[3] Their activity is inhibited by lowering temperature, which is another reason for low storage temperatures.

Thawing

In thawing frozen meats, the object is to reverse the physical changes that take place during freezing and freezer storage. The degree of success that may be attained depends not only on the thawing procedure but to a great extent on the **previous treatment** of the meat. Defrosted meat should be firm, of good color and not subject to drip or leakage. Beef is very susceptible to drip, veal and lamb are less so and pork is least susceptible. The average composition of the muscle fluid or drip which exudes from defrosted beef is as follows: Moisture 85.09 percent, protein (N×6.25) 13.67 percent, ash 1.23 percent, pH 5.50.

According to commercial practice, fresh frozen meats are defrosted in humidified defrosting rooms with temperatures between 40 and 45 F and a relative humidity above 95 percent. If the meats are to be cured, they are sometimes defrosted in sodium chloride brine at temperatures of

40 to 45 F. The rate of thawing is accelerated by immersion in brine because it is a better heat conductor than humidified air.

Quickly frozen meats are not subject to excessive leakage by a fast rate of thawing if the temperature of the thawed meat is not allowed to go above 40 to 45 F. If the meat has been slowly frozen, however, with consequent large extrafiber ice crystals, then a fast rate of thawing is often associated with excessive leakage, particularly when appplied to beef which is frozen a few days after slaughter.[22]

The amount of leakage in thawing meat depends in a large measure on the amount of cut surface in relation to the total surface. For instance, beef steaks which were frozen at −30 F one week after slaughter and stored for three months at −30 F lost 5.35 percent of their weight on thawing at 36 F and 95 percent rh. Under similar conditions beef rounds, with their smaller area of cut surface in proportion to total surface, lost 1.84 percent of their weight.

The following general rules should be observed in thawing meats in order to minimize bacterial and color deterioration: (1) Meat should be thawed at cooler temperatures and not at room temperature unless the product is in small units and is to be cooked promptly; (2) thawed meat should not be refrozen; (3) holding period in refrigerated storage after thawing should be limited.

Disposition and Marketing

Meats are frozen for (1) retail markets; (2) institutional trade which includes hotels, restaurants, institutions, trains, and ships; (3) subsequent use in sausage, cured meats, and canned meats.

Meats which have been packaged and frozen for the retail trade are usually sold to the consumer from refrigerated store cabinets, which will maintain temperatures of 0 F or lower. Actually the temperature in these cabinets is often above 0 F during marketing hours because the doors are opened frequently. The cabinets are rectangular, flat-top models in white enamel finish with capacities of 10 to 20 cu ft.[1] Many models have display windows on top and lighted display boards above the cabinet showing colored pictures of the foods and the price lists. There is a recent trend to open-top self-service cabinets engineered to maintain low temperatures at product levels at all times.

The essential difference between meats prepared for retail trade and those packed for institutional trade is in the size of package. Packages of from 1 to 5 lb are generally prepared for retail trade, whereas packages of from 5 to 100 lb are prepared for institutional trade.

Although figures are not available, large tonnages of frozen meats are processed in one way or another before reaching the consumer. During seasons of heavy hog marketing, millions of pounds of pork hams and pork bellies are packaged in moisture-vapor resistant material and frozen. During seasons of relatively light hog marketing these cuts are thawed, cured, and smoked before they move into the channels of distribution.

Likewise millions of pounds of boneless meats are packaged, frozen and stored to be used later in the manufacture of sausage products, canned meats, and pickled meats.

Transportation

The conditions of temperature, humidity and air movement recommended for freezer storage of meat products are those recommended for the transportation of frozen meat products. In practice, it has not always been possible to meet these requirements, but marked improvements are anticipated.

During the war, a large volume of frozen meat was moved by rail to the seaboard and then transferred to **refrigerated ships** for overseas shipment, the standard railway **refrigerator car** being used for rail transport of the frozen product. Temperatures of +10 to +25 F are maintained in these cars by filling the bunkers with a mixture of 75 to 80 percent coarsely crushed ice and 20 to 25 percent salt by weight. Low ice capacity of the bunkers and hot weather are factors which prevent the maintenance of the desired lower temperature. The cars are prechilled before loading and they are re-iced as often as is necessary to maintain temperature. Frozen meats shipped according to this procedure arrive at the seaboard in satisfactory condition, although it is generally agreed that lower temperatures are to be preferred. Railway cars refrigerated by dry ice have

been developed which hold the temperature of frozen meats at sub-zero temperatures. Dry ice is often used in the standard railway refrigerator cars to give added refrigeration for protection of frozen products.

Refrigerated trucks have long been used successfully for shipment of ice cream and more recently they have been used extensively for moving frozen foods of all kinds. Refrigeration may be supplied by a mechanical compressor operated by a small gasoline engine or through a power take-off on the truck engine in connection with hold-over plates containing an eutectic solution. These plates may also be refrigerated to freeze the eutectic solution by means of a stationary compressor located at the plant or warehouse. These hollow plates vary in size; for example, $60 \times 30 \times 2\frac{3}{4}$ in. is a common size.

Occasionally dry ice is used as a refrigerant in trucks handling this type of product. Temperatures of 0 F or lower are maintained. Still another method uses a blower system.

Cooking

Frozen meats may be cooked directly from the frozen state. They may be partially thawed or entirely thawed. When cooked directly from the frozen state, it is necessary to extend the cooking time beyond that recommended for unfrozen meats. For instance, 4-lb frozen beef rib roasts require from 10 to 15 min per lb longer cooking at 325 F than do similar unfrozen or thawed roasts. Sometimes when broiling or frying small cuts of meat direct from the frozen state, it is desirable to reduce the cooking temperatures to prevent a condition in which the superficial tissues are overcooked by the time the internal temperature of the meat has reached a satisfactory level. This may be accomplished in broiling steaks by increasing the distance between the surface of the steak and the source of heat. For satisfactory results, it may be desirable to partially thaw thick steaks to insure the correct inside temperature without overheating the surface tissues.

Frozen Cured Meat

Most of the frozen pork, beef, lamb, and veal is fresh product. However, there are millions of pounds of pork hams and picnics which are frozen and stored in sodium chloride brine. These products may be considered as being partly cured.

Sometimes cured meats are packaged in moisture-vapor resistant paper or film and frozen and stored according to the procedure used for fresh meats. However, the storage life of these cured products is generally much shorter than that of fresh frozen products, because of the greater susceptibility of cured meats to rancidity.[5] The shorter storage life of cured meats stored in air as compared to cured meats stored in brine is attributed to the greater susceptibility of fat to oxidation while stored in air.

Lea[15] compared the keeping quality of frozen cured bacon and frozen fresh pork. He reported that the salt (NaCl) in the cured bacon apparently activated the fat-splitting lipoxidase enzyme system, thereby adversely affecting keeping quality. He recognized the oxidizing effect of sodium nitrite, which is used in curing pickle, but he stated that at the pH level of cured meat, it had little effect.

Recently numerous varieties of frozen cooked meats have appeared on the market. These items may offer interesting possibilities.

Industry

Figures are not available on the total volume of meats which is frozen annually in the United States; however, estimates may be made from figures which are available.[2] The frozen stocks on hand as of January 1, 1944, are reported as follows: pork, 206 million pounds; beef and veal, 212 million pounds; lamb and mutton, 36 million pounds; trimmings and variety meats, 137 million pounds; or a total of 591 million pounds, which amounts to 3.5 per cent of the total U. S. inspected kill of beef, lamb, veal, and pork for 1943. In 1938, which was a normal prewar year, this percentage was 2.4 when figured on the same basis. In prewar years the average freezer storage period for all frozen meats was indicated to be three months; consequently during 12 months there would be four turnovers of product, so that the actual percentage of the total production which is frozen may be four times the 2.4 percent, which amounts to

9.6 per cent of the total U. S. inspected meats or over one billion pounds. These figures do not take into consideration the meats which are not processed in U. S. inspected plants, nor has any estimate been included of the volume of meats handled in freezer locker plants.

Indications point to a rapid expansion of the frozen food industry. The degree of success which will attend such an expansion will depend largely upon the quality of the product. This means that research and development should go forward at an accelerated rate on all phases related to frozen foods.

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6. POULTRY AND EGGS

THE purpose of refrigerating poultry and eggs is to maintain and preserve quality. Refrigeration may improve quality in certain instances but it is generally recognized that its primary value is the maintenance of existing quality. Freshly laid eggs are at their peak with respect to quality, and poultry is at its maximum quality within a short time after stock is dressed. Refrigeration is employed to maintain this top quality.

Numerous methods have been worked out for the successful handling of poultry and eggs under refrigeration. These developments have not been haphazard but have been the result of much scientific endeavor. The scientific literature contains reports from many and diverse sources on refrigeration studies. Development of improved methods of handling products before, during, and after refrigeration now permits them to be held from seasons of over-production to seasons of scarcity, and allows their orderly transfer from rural to urban centers. Even when subjected to long storage periods, refrigerated products possessing original freshness can be placed in the hands of the consumer.

Refrigeration of poultry and eggs is so commonplace today that the art is merely taken for granted. Mechanical refrigeration has influenced the activities of the poultry industry and also has played an important role in shaping our present economic and social structure. Distribution of our population is dependent to a large degree upon mechanical refrigeration. The shift from rural life to urban life would have been difficult, if not impossible, without refrigeration.

CARL H. KOONZ, Author Chapter 6. Born 10/23/07 at Gresham, Wis. Educated at Carroll College, AB, 1931; Northwestern Univ., AM, 1934, PhD, 1937. Research Biologist, Research Labs., Swift and Co., 1937 to date.

Author of articles in several scientific and trade journals on microscopy of foods and the processing, freezing, storage and quality control of poultry and poultry products.

Member of Amer. Assn. Adv. of Science; Amer. Soc. Parasitologists; Amer. Microscopical Society; Inst. of Food Technologists; Inst. Amer. Poultry Industries (Operating Research Committee 1943 to date), representing Swift and Company; Biological Photographic Assn.; Poultry Science Assn.; The World's Poultry Science Assn.

At present, Research Biologist, Swift and Co., Chicago, Ill.

I. POULTRY

With the aid of refrigeration the poultry industry, like many of the food enterprises, has grown into a large industry. The gross farm income from chickens and eggs in 1948[1] was $3,272,708,000. Of this income 66 percent was from eggs, 22 percent from farm chickens and 12 percent from commercial broilers. The meat phase of the poultry industry until recent years was a by-product of the egg production business. In the last 15 years a change has taken place in poultry production during which emphasis has been also placed on producing broilers for meat purposes. In 1934[2] broilers constituted only 4% of all chickens produced; in 1940 this had increased to 14%, and 1948 preliminary figures indicate that it had increased to 29%.

While total production was increasing, the per capita consumption was also increasing, indicating that the greater volume was not altogether a result of an increase in population. The per capita consumption[3] for civilian population in 1934 was 18.8 pounds of dressed chicken and 2.2 pounds of dressed turkey. In 1940 the consumption was 18.7 pounds of chicken and 3.5 pounds of turkey; in 1947 the per capita consumption was 23.4 pounds of chicken and 4.5 pounds of turkey.

Ante-mortem factors directly influence post-mortem quality. Much care is taken by poultry producers to make certain that the **feed formula** contains all the ingredients essential for producing a high quality product and no ingredient which may impart an undesirable odor or flavor. It is also desirable to fatten poultry immediately before slaughter. A well finished bird

has a higher market value because of a better "bloom" and because of the comparative ease with which an excellently flavored product can be obtained.

The conventional practice is to collect the live birds at central dressing stations where stock is prepared for market. The details regarding the procedures at the dressing stations vary throughout the industry, but, in general, they include live inspection, fattening, dispatching, defeathering, chilling, grading, and packing. During **live inspection,** the birds that show evidence of being unwholesome for human food are rejected. It is economical to reject undesirable birds before they have been put through the feeding and dressing operations.

Poultry may be **dispatched** by severing the jugular vein or veins and by piercing the brain. In the case of kosher-killed poultry, it is essential that both jugular veins be severed as well as the esophagus and trachea.

Feathers may be removed by dry plucking immediately after the brain has been pierced. This method at the present time has been almost completely discarded because of the relatively high cost of the operation. In most instances **feather removal** is facilitated by immersing the birds in or by spraying the birds with water. If the temperature of the water is between +170 and +190 F, the method is known as hard-scald plucking, and if the temperature of the water is +124 to +130 F, as semi-scald plucking. The latter method is generally used. The hard-scald method is followed almost exclusively by ice packing, whereas semi-scald plucked poultry can be handled in accordance with any of the standard or conventional methods. The semi-scald plucking method is particularly valuable in preserving the bloom, as skin abrasions are largely avoided.

Conventional practice is to remove the large tail and wing feathers manually, as soon as the birds are removed from the scald tank. Removal of most of the smaller feathers is usually accomplished by means of machines having revolving drums with rubber fingers. Birds then may be dried and immersed in melted wax, heated to approximately +125 to +130 F. The remaining small feathers are removed when the wax is peeled off the bird.

After the feathers are removed, the birds should be thoroughly washed by spraying water over the carcasses. The effectiveness of this procedure for removing surface bacteria has been indicated by Koonz.[4]

Poultry is **graded** according to class, quality, size, and sex. Undesirable poultry that was not detected and discarded during the live inspection, is destroyed when dressed stock is graded. The various classes of chickens include broilers fryers, roasters, capons, stags, fowl, and cocks. Based on the dressed weight, broilers are young birds weighing under 2.5 lb, fryers weigh 2.5 to 3.5, and roasters weigh over 3.5 lb and are sufficiently soft meated to permit cooking by roasting. Stags are young male birds in a state of maturity between roasters and cocks, capons are castrated male birds weighing over 4 lb, and cocks are mature male birds. Fowl are mature female birds of any size. A differentiation in turkeys is made between young hens, old hens, young toms and old toms. Ducks and geese are separated into young and mature birds, without reference to sex. Birds in the various classes usually are separated into groups that do not differ greatly in weight.

An important consideration in grading is determination of **quality. Table 1**[5] summarizes incompletely the U. S. Specifications for standards of quality for individual carcasses of dressed and ready to cook poultry.

Some of the methods of handling poultry have been summarized in **Fig. 1.** In this summary no attempt has been made to follow the course of poultry products such as soup, canned or smoked poultry and other poultry specialty items.

Chilling Poultry

The internal temperature after being dressed in accordance with present commercial methods will be approximately +100 F. The purpose of chilling is to retard deteriorative changes, and hence it becomes desirable to lower the temperature of birds as rapidly as possible. Inadequate chilling results in poultry that is "green

struck" and permits the progressive development of other changes that will impair quality and shorten the length of time that the product will remain saleable. Poultry should be chilled to a temperature of approximately +35 F.

Two principal methods of chilling are commonplace in the industry at the present time. One method is chilling by means of direct contact with a cold liquid medium and the other is chilling in cold air. There are numerous variations, but in general air chilling will leave the skin rather dry whereas liquid chilling will leave the skin moist. When air chilling is employed, rooms are generally held at temperatures below +40 F and it is desirable to maintain temperatures as near +32 F as possible. Poultry intended for freezing is sometimes packed while warm and promptly subjected to effective freezing temperatures and conditions. Sweet and Stewart[6] reported a method of chilling poultry in which stock was subjected to a brine spray for a short time. Before the birds in the test became completely chilled, they were transferred in some instances to a cooler and allowed to come to an internal temperature of +34 to +36 F. This was called the "cold-shock" method and, when a brine having a temperature of +20 F was used, chickens and turkeys were chilled in 25 to 35 percent of the time required in air at +35 F.

Of the liquid chilling methods, the one most commonly employed involves the use of ice as the refrigerant. Poultry can be chilled in a very rapid manner in ice slush. Comparison of the rate of ice slush versus air chilling is summarized in Fig. 2. It has been pointed out by Bailey, *et al.*,[7] that cut-up chickens and eviscerated chickens, when ice is used, cool faster than New York dressed poultry. To cool poultry to 45 F, 112 minutes was required for New

Table 1. Partial Summary of U. S. Specifications for Standards of Quality for Individual Carcasses of Dressed and Ready-to-cook Poultry[5]

U. S. Grade	Quality specifications for individual birds*
A	Normal conformation, breastbone may show slight curve and very small dent. Must be well fleshed with covering of fat over all parts and practically free to free of pin feathers depending on whether dressed or ready-to-cook. No skin tears and cuts on breast and legs allowed. There may be no sewn tears or cuts. There may be no disjointed or broken bones except there may be one disjointed bone in either leg or wing providing no evidence of related bruise or blood clot, however; if chicken is broiler or fryer in addition may have one non-protruding broken bone in a wing if no evidence of related bruise or blood clot. Carcass must be free from bruises and discolorations of flesh on breast and legs.
B	Practically normal conformation breastbone may be dented, curved, slightly crooked. Carcass must be fairly well fleshed on breast and legs and these parts must have sufficient fat covering to prevent distinct appearance of flesh through skin. Carcasses must be relatively free to free of pin feathers depending on whether they are dressed or ready-to-cook. Cuts and tears in chickens must be limited to an aggregate length of 1½″ on breast and legs and 3″ elsewhere, not more than 2 disjointed bones and not more than 1 nonprotruding broken bone. There may be no sewn cuts or tears. Carcass may show discolorations somewhat in excess of that acceptable for A quality.
C	Conformation abnormal, breastbone and back seriously crooked if fairly well fleshed. Legs and wings may be misshapen. Breastbone may be prominent and carcass may lack in fat covering. Pin feathers may be numerous in dressed poultry; ready-to-cook poultry may show scattering of non-protruding pins but must be free of protruding pins and hair. Carcass may have torn skin, disjointed bones and broken bones if these are not related to severe bruises or blood clot. Practically no limit on size and number of areas of discoloration and flesh bruises if these do not render part of the carcass unfit for food.

* Quality designations not applicable to carcasses affected by or showing evidence of disease or condition which may render them unwholesome or unfit for food, or carcasses that are dirty or that contain feed in crop or that show fan feathers on wing tips or garter feathers around hock joints.

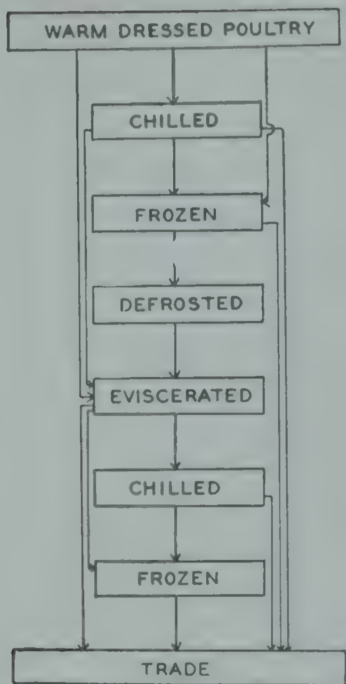

Fig. 1. A Summary of Methods of Handling Poultry.

York dressed birds, 50 minutes for eviscerated birds, and 25 minutes for disjoined or cut-up birds. The rapid chilling of poultry is advantageous, in that it retards deteriorative changes and permits operators to place the stock in freezers or in the trade channels the same day it is dressed. The method of liquid chilling is useful and adequate, providing that the procedure is carried on properly. The temperature of the liquid should be kept below +35 F at all times during the chilling process, and the birds should be removed from the chill tank promptly after adequate chilling. The water in the chill tank should be kept clean and clear at all times, and the containers used for chilling should be thoroughly cleaned at least once daily.

If liquid chilling is adequately performed, the poultry will be in good condition from a bacteriological point of view. Cook[8] conducted an experiment in which five lots of poultry were chilled successively in the same water. The results showed that the bacterial counts generally tended to increase with each lot of poultry, but that the increase was not serious in view of the number of bacteria originally present. The water used in this experiment was held at +32 F. Roberts and Robertson[9] also have shown that the growth of bacteria is extremely slow in water held at +33 F. These results merely serve to indicate that bacteria will not grow rapidly in water held at temperatures that are desirable for ice slush chilling. Studies relative to the product itself, under commercial conditions of handling, demonstrate that it does not become unduly contaminated with bacteria during the ice slush chilling process.

Freezing, Storing and Defrosting Poultry

The purpose of freezing poultry is to maintain and to preserve quality. It, therefore, becomes apparent that it is desirable to place the product in the freezer before deteriorative changes have proceeded to the extent that quality is impaired.

Many reports appear in the scientific literature regarding the freezing of poultry. Tressler and Evers[10] give particular attention to chilling, freezing and the preparation of stock for freezing. It was

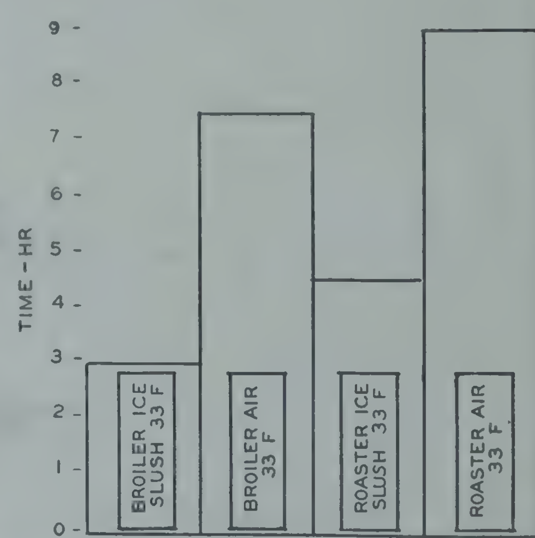

Fig. 2. Time Required for New York Dressed Birds to Chill to 37 F Internal Temperature.

pointed out by Koonz and Ramsbottom[11] that very slowly frozen poultry appears dark, with very large ice crystals of the extra-fiber type. When poultry is frozen at a temperature that insures a rather natural bloom, the ice crystals are smaller and more numerous, but are still principally of the extra-fiber type. Ice crystals are small and are of the intra-fiber type when freezing is sufficiently rapid to insure a white appearance. Ramsbottom and Koonz[12] showed that ice crystals became progressively larger in beef steaks as the time between slaughter and freezing increased. This also is true for poultry.

DuBois, Tressler and Fenton[13] studied cross-sections of chicken muscle after employing different methods and conditions of freezing. Chickens were frozen with the Birdseye multiplate freezer and in air, with and without air blast at +10, 0, −8 and −25 F. The effects of the different rates of freezing were illustrated by means of photomicrographs. Large ice crystals were found to be present in tissues slowly frozen at +10 F without air blast, whereas the faster methods of freezing effected the formation of a large number of very small crystals. The conditions and influences that may affect the distribution, size and number of ice formations in frozen poultry tissues are many.

Steaks have a large area of cut surface in relation to volume of meat, meaning that rapid freezing or intra-fiber freezing is desirable if drip is to be held at a minimum after the product has been defrosted. This is not true for poultry, as pointed out by Sair and Cook[14] and Koonz and Ramsbottom.[15] In order to get poultry meat to drip noticeably, the muscle must be finely minced or hashed. It becomes obvious that freezing rates are not so critical in the case of poultry as they are for some cuts of meats, and certain fruits and vegetables.

It was once common to use refrigerating rooms of about +15 F. Pennington[16] studied changes that occurred in poultry when held for as long as three years at relatively high temperatures, indicating that storage for 10 months was feasible. The trend now is to employ more rapid methods of freezing. Temperatures of refrigerating rooms have been lowered, and the air blast technique has been introduced in order to accomplish a sharp or quick freeze. During recent years methods for securing a quick freeze have been developed, employing direct immersion of the product in a chilled liquid, or placing the product in indirect contact with the refrigerant. Poultry is generally frozen in freezers maintaining air temperatures between 0 and −20 F. These temperatures are adequate for most types of packs, although faster freezing is not undesirable. From quality considerations, any freezer or method of freezing is adequate that permits stock to have a natural bloom after being frozen.

Growth of bacteria is substantially and effectively retarded when poultry is frozen and held at suitable storage temperatures. As indicated in the report by Harshaw and others,[17] all the bacteria present will not be destroyed during freezing or during freezer storage. Consequently, poultry should show relatively low bacterial counts when frozen; otherwise when defrosted it will be subject to rapid deterioration. The danger of visceral taints being imparted to the edible tissues in dressed poultry, if the product is frozen while in strictly fresh condition, is negligible. Stewart, Hanson and Lowe[18] pointed out that if dressed birds are brine-spray frozen within 5 hr after dressing, they can be held for 6 months in storage prior to evisceration and remain superior even to birds adequately chilled and eviscerated 18 hr after dressing, stored for the same period. It was indicated by Koonz and Ramsbottom[19] that freezing and defrosting of young chickens was responsible for darkening of bones.

During the freezing and defrosting processes, some of the heme pigment normally contained in the interior of the bones of particularly young chickens leaches out through spongy areas, and discolors the adjacent tissues. This in no way affects the palatability of the product, because the pigment is a natural tissue pigment which, after being cooked is known as hematin and is responsible for the cooked appearance of all meats. The rate of freezing has no marked influence in preventing this

discoloration. Also, the period of time between slaughter and freezing had no significant effect on the color of poultry bones or on the displacement of pigment from the interior of the bones to adjacent tissues. Woodroof and Shelor[20] reported that the bone darkening increases slightly during the first few weeks of storage at 0 F and then remains constant for several years.

During storage, poultry may become dehydrated, yielding a condition known as "freezer burn." Tressler[21] has reviewed the literature and has made helpful suggestions as to preventing surface desiccation Freezer burn can be controlled by humidification, the lowering of storage temperatures, or by packaging the product adequately. Aside from adversely affecting the appearance of the product, freezer burn, unless it is severe, does not impair quality. If storage temperatures of 0 F. or lower are maintained, freezer burn is usually the factor limiting the length of time that poultry can be held in storage.

Koonz, Trelease, and Robinson[22] reported the results obtained, when holding poultry in storage at −20, −10, 0, +10, +20 and +28 F. A record was made at various intervals over a period of a year concerning color, freezer burn, moisture loss, peroxide values, and palatability scores of fat and meat. The results indicated that at storage temperatures of 0 F or lower, freezer burn was usually the factor which limited the time that poultry could be held in storage.

Wills, *et al.*,[23] found that the appearance of poultry suffered greatly when stored at +20 F. The most serious defects were microbiological changes, desiccation, and development of "old" odors. At 0 F, changes affecting quality were less serious. Serious changes in flavor and juiciness occurred in poultry which had been frozen 3 to 9 months at temperatures of +10 F and higher. Storage at 0 F or below resulted in minimum changes, even after 9 months. Wills, Lowe, and Stewart[24] in reporting results of palatability studies, indicated that storage poultry was less juicy than fresh control poultry. This condition was less serious when poultry was held at −10 F than when held at +10 F.

During recent years, the results of many studies have been reported dealing with the development of rancidity in poultry. The influence of dietary factors, handling prior to freezing, storage temperature, and differences in length of storage period, on the development of rancidity in poultry has been given special attention.

Poultry fat will become rancid during very long storage periods or if the storage temperatures are exceedingly high. Cook and White[25,26] studied the development of rancidity in poultry fat and found that rancidity of an order that may affect quality could be obtained by holding birds 5 to 6 weeks at +32 F, followed by a 27-week storage period at +10 F or by holding poultry for 87 weeks at +10 to +5 F.

Wagoner, Vail, and Conrad[27] found that withholding feed from poultry for 16 hours prior to killing tended to increase storage stability of fat very slightly when poultry was held for 9 to 20 months at relatively high (+8.6 F) storage temperature. These investigators[28] also reported that holding dressed poultry at cooler temperatures for one day or longer before eviscerating and freezing, decreased the stability of the poultry during storage. Hite, Kloxin, Kummerow, Vail and Avery[29] found that the stability of fat was influenced by various dietary factors. Supplements of choline, ethanolamine or fat were included in the diet of turkeys. The fat was analyzed after 4, 9, and 12 months' storage at +8.6 F. The results indicated that all birds were acceptable after 4 months of storage; after 9 months' storage, all birds were acceptable except those which had received supplements of 2% hydrogenated fat, 10% alfalfa meal, or 1% linseed oil. After 12 months' storage, only the lot receiving the typical turkey ration plus ethanolamine or choline was acceptable. A storage temperature of +8.6 F is rather high, and in all probability, results would have been different, if the product had been held at a more conventional storage temperature. The evidence indicates that the fat in poultry held at 0 F or lower during the normal storage period will not become sufficiently rancid to impair quality.

Under ordinary conditions, it is desira-

ble to keep the poultry frozen until shortly before it is to be consumed. The general procedure is to defrost in air or in water. Box-packed frozen poultry usually has started to soften when it reaches the retail establishments and under these circumstances can be handled conveniently. Frozen poultry intended for evisceration is usually defrosted in water. If evisceration follows defrosting immediately, the method of defrosting in clean, clear water is entirely adequate.

Critical Review of Methods of Handling Poultry

It has been indicated in Fig. 1 that there are numerous methods of handling poultry. Refrigeration must be relied upon to maintain and preserve post-mortem quality. Methods of handling that permit the effective application of refrigeration may be considered desirable and adequate. It is necessary to understand the causes of post-mortem deterioration before it is possible to evaluate these methods.

Deterioration is due to physical and chemical changes as well as microbiological growth on and within the tissues. It is difficult to treat these as three separate entities responsible for deteriorative changes because generally they are proceeding simultaneously and are interdependent. The influences which primarily limit the length of time that poultry will remain saleable are the development of visceral taints and deterioration due to microbiological growth. The quality of dressed poultry generally will be impaired seriously by **visceral taints,** before the other deteriorative influences have proceeded to the extent that they render the product undesirable or unfit for consumption. Suitable methods of handling dressed poultry must employ refrigeration that will effectively arrest or prevent the development of visceral taints.

Numerous investigators during recent years have reported the results of experiments relating to methods of preventing visceral taints. In conducting studies of this type, the odor of cooked product is important in evaluating quality. This has been emphasized by Vail and Conrad.[30] In studying palatability changes occurring in frozen poultry, it was concluded, that the most reliable method of determining organoleptic changes was to cook the bird in moist heat in a covered container and then evaluate odor, after the bird has cooled slightly. It was pointed out by Stewart, Lowe and Morr[31] that poultry held at +35 F for 48 hr showed evidence of deterioration in thigh and breast muscles. Presumably these flavors were imparted to the edible tissue by the organs in the body cavity. Studies carried on by Fitzgerald and Nickerson[32] seem to indicate that birds can be held at +31 to +33 F for 8 days without risk of off-flavor development.

The extent to which taints will be imparted to the edible tissue in poultry held at +36 F will be found summarized in Table 2. The birds used in this study were held as dressed birds for ¼, 1, 3, 6, 9, and 12 days before being eviscerated. At each of these time intervals three were eviscerated and then frozen. At the completion of the 12-day period, one bird from each of the time intervals was cooked and scored. The inspectors were requested to indicate whether deteriorative odors and flavors were (5) pronounced, (4) slightly pronounced, (3) perceptible, (2) slightly perceptible, or (1) imperceptible. The scores when averaged indicated that deteriorative taints, largely of visceral origin, became perceptible on the sixth day. In conducting these tests no seasoning whatsoever was used and members of the tasting panel were instructed to be very critical. Consequently it is felt that a rating of perceptible is required before the score has much significance.

Table 2. The Development of Deteriorative Taints in Dressed Poultry Held at 36 F

Days held at +36 F	Flavor evaluation*	Aroma evaluation*
¼	1.25	1.25
1	1.25	1.00
3	2.00	1.50
6	3.25	3.00
9	2.75	2.50
12	3.75	4.00

* Criteria used in evaluating taints: 1.0 = imperceptible; 2.0 = slightly perceptible; 3.0 = perceptible; 4.0 = slightly pronounced; 5.0 = pronounced.

In case of storage at a somewhat higher temperature, deteriorative taints that will lower quality develop at a much faster rate. This can be seen by referring to **Table 3.** This experiment was conducted in exactly the same manner as that mentioned above for +36 F except that the product was held at +50 F. It will be noted that taints that may interfere with quality develop rapidly when stock is held at high temperatures. In contrast, freezer temperatures will prevent the development of visceral and other deteriorative taints in a very effective manner. Koonz and Trelease[33] found, that the retention of kidneys, in otherwise eviscerated birds was not likely to impair the quality of the product. Of the body cavity contained organs, the intestines were primarily responsible for the development of objectionable odors and flavors in poultry.

Table 3. The Development of Deteriorative Taints in Dressed Poultry Held at +50 F

Days held at +50 F	Flavor evaluation*	Aroma evaluation*
¼	1.00	1.00
1	1.00	1.00
3	3.25	3.00
6	4.00	3.50
9	4.25	4.00
12	4.75	4.50

* Criteria used in evaluating taints same as in Table 2.

Bacterial growth proceeds on poultry flesh in very much the same manner as it does on other meats. **Table 4** demonstrates the gradual increase in the bacterial counts for poultry held at +50 F. The birds had previously been chilled in a +36 F coole for 24 hr. The dressed birds were then box-packed and frozen; whereas the other lot was eviscerated, box-packed, and frozen The stock was then placed in a +50 F constant-temperature room, and bacterial determinations were made on the skin, dark meat, and white meat on successive days

It will be noted that the skin shows a considerably higher bacterial coun throughout the four-day holding perioc than the dark or white meat. Results are also interesting because they make direc comparison between the rate of deterioration in dressed and eviscerated poultry The eviscerated stock showed a somewha higher bacterial count at the end of the fourth day. In a very general way, it ca be stated that the eviscerated birds showe the same degree of bacterial deterioratio at the end of the three-day holding perioc at +50 F that the dressed birds showed a the end of the four-day holding period.

Temperatures have a very marked influence on the rate of bacterial growth Studies, based on total bacterial counts have shown that birds held at +36 F fo two weeks are somewhat similar to bird held at +50 F for five days or birds held a +75 F for one or two days. The bacteria flora found in poultry meat consist chiefl of the genera: *Achromobacter*, *Pseudomonas*, *Micrococcus*, and *Flavobacteriun*

The importance of adequate refrigeration in controlling the development c visceral taints and bacterial growth as we as other influences causing deteriorativ changes becomes apparent. The post-mor tem "life" of poultry may be entirel

Table 4. Comparative Bacterial Counts for Frozen Boxed Poultry, Dressed and Eviscerate

Style of dressing	Tissue	Bacterial count per gram of tissue for birds held at +10 C (+50 F)*			
		1 day	2 days	3 days	4 days
NY dressed	Skin	110,000	1,300,000	2,200,000	19,000,000
Eviscerated	Skin	170,000	280,000	1,700,000	80,000,000
NY dressed	Dark meat	230	3,700	43,000	220,000
Eviscerated	Dark meat	3,800	600	3,600	6,000,000
NY dressed	White meat	40	500	9,000	20,000
Eviscerated	White meat	1,000	300	16,000	1,400,000

* Difco-Nutrient Agar plates, incubated at +20 C (+68 F) for 3 days.

spent in one day if it is subjected to sufficiently high temperatures, whereas if temperatures are sufficiently low, quality may be maintained for an indefinite period of time.

Dressed poultry is customarily handled as ice-packed stock, box-packed unfrozen stock, or box-packed frozen stock. Ice-packed poultry should be handled rapidly, since the ice will melt, permitting the temperature of the product to rise with the consequent development of deteriorative changes. In addition, as is well known, bacteria flourish more abundantly on wet surfaces than on dry surfaces. Box-packed unfrozen poultry should be held in a cooler maintaining a temperature of about +35 F, particularly if product is to be held for several days. Temperatures higher than this will permit the development of visceral taints and other deteriorative changes that will soon lower quality. Even under the very best cooler conditions it is not advisable to hold unfrozen dressed poultry for long periods of time, since there is danger of visceral taints being imparted to edible tissues. The main objective in handling dressed poultry intended for subsequent freezing should be to get it into the freezer and frozen before the onset of visceral taints or other deteriorative changes. This poultry can then be kept in the freezer for a very long period if the storage temperatures are sufficiently low and if the product is adequately protected from "freezer burn."

Pennington, Witmer and Pierce[34] and others conducted extensive experiments in the comparative rate of decomposition for undrawn, wiredrawn, Boston drawn, and full-drawn poultry. Relatively high temperatures were employed and under the conditions of the experiment the dressed birds withstood the rigorous handling conditions better than the partially drawn or full-drawn birds. Improvements in methods of handling poultry, particularly with regard to sanitation, refrigeration, and transportation, now permit the successful merchandising of drawn or eviscerated poultry.

It is generally believed that eviscerated poultry will deteriorate at a more rapid rate than dressed poultry. When bacterial counts alone are relied upon to evaluate quality, drawn or eviscerated poultry should show more rapid deterioration than dressed poultry since, during the removal of the body cavity contained organs, stock usually suffers some further microbiological contamination. The product also is generally subjected to more water than dressed poultry, and a wet surface favors bacterial growth and development. Bacterial considerations alone are not sufficient to evaluate quality, since they do not reflect the development of visceral odors and flavors. When visceral taints are taken into consideration it is just as reasonable to maintain that dressed poultry will deteriorate more rapidly than drawn or eviscerated poultry. Post-mortem quality can be preserved and maintained in either dressed or drawn poultry when stock is properly handled. Under many circumstances quality can be maintained more easily when product is handled as drawn or eviscerated poultry.

The growth of the eviscerated poultry industry has not been spectacular; in fact, it has been extremely slow. Unfortunately, operators in many instances have not understood how poultry should be handled prior to evisceration. Too often the poultry was "old" before it was eviscerated and frozen. Poultry may be eviscerated warm, after chilling, or after freezing and defrosting. The warm evisceration of poultry, a relatively new method, appears to be a most desirable one in that the poultry has had no opportunity to develop visceral taints. This poultry should be placed in a freezer soon after it has been eviscerated, or used promptly by the trade as unfrozen or ice-packed stock. In dealing with chilled dressed birds, it is desirable that the stock be eviscerated not later than the day following dressing, although the dressed birds can be held for several days before being eviscerated if special care is taken to hold the product at +36 F or lower.

The tendency in the poultry industry has been to centralize evisceration procedures. Consequently, it has become a practice to eviscerate defrosted dressed stock and then to freeze the eviscerated birds again. Unless this type of poultry is han-

dled in a specific manner, visceral taints are likely to be present. The temperature and length of time that dressed birds are held, both prior to freezing and after defrosting, contribute to deterioration. The importance of promptly freezing dressed poultry intended for subsequent defrosting and eviscerating is vividly demonstrated in the studies by Stewart, Hanson and Lowe,[18] as cited.

Trelease and Koonz[35] have found that the quality of poultry is seriously impaired by visceral taints when defrosted dressed poultry is held at +50 F for one day or more prior to evisceration, and quality is definitely impaired even when defrosted dressed poultry is held at +36 F for a period of one day. Dressed poultry intended for freezing and subsequent evisceration should be placed in a sharp freezer within 24 hr after it is dressed and should be held frozen. It is even more desirable to freeze this poultry on the same day it is dressed. It is satisfactory to defrost this poultry in water, providing the water is kept clean and clear, and providing the poultry is eviscerated immediately after becoming defrosted.

During the last few years more poultry is being packed in ice, either in crates or in barrels. It is estimated that about 40% of the total volume is handled in this way. Poultry may be sold to consumers New York dressed, drawn, or disjointed. It is not uncommon to sell poultry by the piece, for example, all thighs or all wings. The poultry is often displayed in crushed ice. As pointed out by Newell, Gwin, and Jull,[36] this method of displaying poultry has the advantage of preventing dehydration and gives the poultry a fresh appearance.

Disjointed poultry, in particular, is packaged attractively. The pieces are placed compactly in cartons or packages, and this affords good protection for product, if placed in freezer storage. Wagoner, Vail, and Conrad[37] indicated that the reduction in exposed surface, as a result of the compactness possible with disjointed poultry, improves the storage stability appreciably.

Poultry is transported to market largely by means of refrigerator cars, motor truck, or railroad express. Refrigerator cars are generally iced using about 10 to 20% salt, and an attempt is made to hold the car temperature below freezing. Motor trucks may be equipped with refrigeration equipment. Much of the ice-packed poultry is transported in motor trucks.

The importance of adequate refrigeration in chilling, freezing, transporting, and displaying poultry cannot be overemphasized. It is the principal method that the poultry industry has for preserving quality of the product between the time of production and consumption. Refrigeration is largely responsible for the growth and development of the poultry industry.

II. EGGS

Country receivers grade and pack eggs procured from farmers. These eggs are eventually placed in the trade channels as shell eggs, frozen eggs, or dried eggs. The quality of an egg is usually determined one or more times while it is being passed along the trade, by transmitting light through the egg, which permits visual inspection of its interior. In evaluating its quality, both external and internal characteristics of the egg are considered.

The character of the shell, air cell, yolk and whites, determine whether eggs are U.S.D.A. grade AA, A, B, or C. According to U.S.D.A. weight classification, eggs are placed in one of six categories as follows: jumbo, 30 ounces per dozen; extra large, 27 ounces; large, 24 ounces; medium, 21 ounces; small, 18 ounces; peewee, 15 ounces. Most eggs are hand candled using a candling lamp. During recent years, candling machines have been introduced in which eggs are put on a conveyor, brought to the candler in a single row, and rotated mechanically as they pass over the light. The candler removes checks, undergrades, and inedible eggs.

The interior quality of an egg may be observed directly by breaking it into a flat receptacle. The Cornell grade permits the evaluation of quality on the basis of the way in which the broken-out eggs "spread." Numerical ratings from 1 to 5 are used, with the former representing eggs covering a small area with thick white and firm high yolk, and the latter representing eggs covering a large area with thin watery

white and likely a spreading yolk.

The progressive liquefaction in eggs, caused particularly by high temperatures, may be measured by determining the yolk index and the albumen index. The height is divided by the width of the yolk in calculating the yolk index. The albumen index is the ratio obtained by dividing the height of the apparent dense albumen by the average of its long and short diameters.

Shell egg production in the United States started when the country was first colonized. It was a home flock enterprise for many years. Commercial production of eggs was stimulated by improvements in breeding, management, and nutrition. Over the years there has been a very marked increase in rate of lay. During recent years, the record of performance phase of the National Poultry Improvement plan and egg laying contests sponsored by certain states have encouraged greater production per hen. Some of the breeds used for egg production purposes include White Leghorns, New Hampshires, White Plymouth Rocks, Barred Plymouth Rocks, Rhode Island Reds, and crosses of various types.

All eggs are not of similar quality at the time they are laid. Many reports appear in the scientific literature dealing with factors influencing egg quality prior to oviposition. Egg quality is influenced by breeding and by the diet of the hen.

Blood and meat spots are not uncommon in eggs. A meat spot appears to be a blood spot, that has undergone certain degenerative changes. They are due to rupturing of blood vessels in the reproductive tract of the hen. Quinn and Godfrey[38] indicated that there may be an inherited predisposition to the production of blood spots. Nalbandov and Card[39] indicated that bleeding can be reduced substantially by permitting affected hens access to grass. Blood clots were found less frequently in eggs from Leghorn flocks, than in eggs from heavier breeds.

The color of the yolk in newly laid eggs is dependent upon deposition of carotinoid pigments in the fat particles. The pigments are of dietary origin and are found in yellow corn and green plants, including the grasses.

The character of the albumen is influenced by a wide variety of factors, including disease, breeding, and physiological condition of the hen. Dietary factors have not been shown to have any particular influence on quality of the albumen. Knox and Godfrey[40] state, that it is evident that the ability of a pullet or hen to secrete a greater or lesser amount of thick albumen in eggs is an inherited characteristic, and that chickens can be bred to produce eggs with a greater percentage of thick albumen, than is generally found in eggs at the present time. Byerly[41] has pointed out that it is possible through selection to develop lines that have the capacity to produce eggs with "heat resistant" whites.

Berg, Bearse, and Hamilton[42] found, that Newcastle disease is responsible for a marked decrease in egg production, an increase in roughness of shell, and a loss in albumen quality in some birds, which may be of a permanent nature. Parnell[43] indicated, that eggs from hens with Newcastle history did not keep as well in storage as eggs from hens that did not have a Newcastle history.

The physiological condition of the hen, aside from that brought about by disease, exerts an influence on the character of the albumen. Wilhelm and Heiman[44] found there was a downward trend in albumen quality from October until July, apparently correlated with the length of time the hens had been in production. Berg and Bearse[45] forced hens to molt and, for hens in production for 12 months, noted an improvement in albumen quality as well as other improvements in quality.

Maintenance of Quality

The freshly laid egg is at its peak in quality. Refrigeration must maintain this quality, and effectively prevent deteriorative changes brought about by physical and chemical changes and microbiological growth. Quality maintenance is dependent upon the success attained in arresting changes due to these influences. Essential steps include temperature control, humidity control for the purpose of preventing excessive evaporation, sanitation designed to prevent microbiological contamination, and avoidance of all materials that may

impart unfavorable odors or flavors to the eggs.

High **temperatures** must be avoided if quality is to be maintained. Such temperatures permit liquefaction of the contents with a weakening and spreading of the yolk. Accompanying these changes is a transfer of water from the white to the yolk. It is well known, that the quality of eggs produced during the warmer months is likely to be inferior to that obtained during the cooler months. High temperature appears to be the most important influence responsible for lowering the quality of eggs procured during the warm season of the year, and a sharp decline in quality may be noticed with the onset of summer temperatures.

High temperatures should be avoided on farms by placing eggs in wire baskets or other suitable containers and then holding them in cellars or other rooms that maintain temperatures of less than +60 F.

Refrigerators may be used effectively by farmers to chill and hold eggs and their use should be encouraged. During seasons of over-production, shell eggs are placed in storage coolers where the temperature is carefully controlled. When placed in storage, shell eggs are usually held at temperatures of +29.5 to +30 F.

The loss of moisture from eggs should be prevented. This becomes particularly important when eggs are held in storage. It has become a rather common practice in industry to immerse eggs briefly in mineral oils or other processing fluids before placing them in storage. It is desirable to apply the oils to relatively newly laid eggs. Much investigational work has been conducted, designed to determine the most suitable procedure to follow in oiling eggs. Lorenz,[46] in comparing performance of ten mineral oils, reported that oil persistency, as estimated by measuring the evaporation rate of the oil itself, was most closely related to the efficiency of the oil. Gibbons, Michael, and Irish[47] found that mineral oils with Saybolt viscosities of 70 to 100 at +100 F were more suitable for maintaining egg quality than oils of lower viscosity. Little difference was found in the effectiveness of the oils when used at temperatures of 76, 100, and +130 F.

The humidity in the egg storage room is not so critical when egg shells have been coated with oil. A relative humidity of about 85% in storage rooms is adequate for oiled eggs but, when oil is not used, a higher relative humidity is desirable to prevent excessive moisture loss from the eggs. With higher humidities the control of mold may be a problem. Proper oiling of shells along with suitable storage room humidity effectively retards loss of moisture and coupled with proper control of temperatures, constitute vital factors in the successful prevention of quality deterioration.

Eggs may deteriorate because of microbiological growth. Mold may develop on storage shell eggs, particularly if the humidity is extremely high or if adequate attention is not given to **sanitation** and **air circulation.** Also, shell eggs may contain bacteria that gain entrance into the interior, and in such cases, temperature control is very important.

The shell of an egg is fairly porous, and consequently eggs readily absorb odors. These odors may be imparted to eggs by other products or items simultaneously held in the storage rooms, or by materials used in packing the eggs, such as faulty fillers and flats.

The proper selection and grading of eggs, suitable control of temperature and humidity, adequate sanitation and avoidance of materials that may impart foreign taints, represent basic and fundamental steps that should be taken in order to preserve quality. Numerous supplementary **procedures** have been developed to help maintain quality.

On a more or less experimental basis, eggs have been stored in atmospheres containing preservative gases, particularly carbon dioxide. This has some value in maintaining a desirable pH in the eggs and in preventing detrimental changes. The stabilizing of shell eggs by **heat** is also being tried. Such a process has been reviewed and described by Funk.[48,49] Heat treatment of shell eggs reduces spoilage caused by micro-organisms, permanently arrests embryonic development and stabilizes the albumen and vitelline membrane. It is too early to predict the extent and degree to which heat-stabilization methods will be used by the industry.

Considerable emphasis is also being

placed on new and improved methods of washing and sterilizing shell eggs. An egg with a clean shell is desirable for table use, and for the production of liquid eggs intended for freezing.

Frozen Eggs

The frozen egg industry has grown to enormous proportions. Pennington[50] has pointed out that eggs were removed from shells, frozen in cans and placed on the market as early as 1889. During the very early growth of the industry it was a common practice to break and freeze eggs that were edible and palatable but that, because of small size or slight cracks in the shell, were not readily marketable. The demand for a high-grade frozen egg product has been steadily growing and, as pointed out by Heitz,[51] dealers may break high-grade eggs from current receipts for their frozen supply.

The frozen egg industry has been particularly helpful in that **surpluses** can be handled during the over-production season and the trade can be continually provided with a product that is most useful and desirable. In 1948, with a government support program, approximately 85% of eggs produced were used as shell eggs, 6% frozen eggs, 5% dried eggs, and 4% for hatching purposes. In 1948 about 345,192,000 lbs. liquid eggs were frozen. During normal years the product is used especially by the bakery, mayonnaise, noodle and candy industries.

Egg-breaking plants should be located in areas producing good eggs. Prior to going to the breaking rooms, eggs may be candled; only the sound eggs, or eggs of good interior quality, should be selected for breaking. It has been pointed out by Tressler and Evers[10] that for frozen products generally, only good raw material will result in a good thawed product.

Great emphasis should be placed on sanitation in the breaking rooms. The walls, ceiling and floor of the room should be finished with a material that can be washed and cleaned readily and thoroughly. The tables, benches, or racks should also be constructed so that they can be kept clean. Equipment in the breaking rooms such as trays, knives, and cups, must be of such design that it can be washed easily and it must be sterilized frequently. (For standards, see Table 1, p. 61.)

The eggs generally are broken one at a time and placed in a cup holding not more than two to four eggs. These eggs, if satisfactory in appearance and odor, are emptied into a larger container. The eggs are eventually placed in a mixer and agitated until the mixture becomes homogeneous. The usual procedure is to place the strained liquid eggs in containers holding up to 30 lbs.

Pasteurization of liquid eggs has been studied intensively during recent years. Stewart[52] reported that results of experimental studies indicate that effective pasteurization temperatures are 142 F for 3 minutes for liquid whole egg, 142 F for 2 minutes for liquid yolk, and heating to 134 F for liquid white. Under these conditions about 99% of the bacteria present will be killed.

Frozen eggs may consist of a mixture of whites and yolks in natural proportions, or the whites and yolks may be frozen separately. Yolks intended for freezing must be especially treated if a good thawed product is to be realized. It has been pointed out[53] that the solids do not reabsorb the water, nor is the precipitated lecithin recombined in untreated yolks; consequently, it is generally the custom to add sugar, salt, or sometimes glycerine, prior to freezing. The quantity of dextrose and salt may range from 5 to 10 percent and glycerine from 10 to 20 percent.

Liquid eggs are usually frozen and held at 0 F or lower in order to maintain quality. Winter and Wrinkle[54] reported that a 30-lb container of whole eggs will freeze to 0 F in still air in 28 hours at −24 F, in 32 hours at −15 F, and over 44 hours at 0 F. Air blast freezing and especially constructed quick freezing units may be used to secure a much more rapid freeze.

In order to have a uniform product giving uniform performance, standards have been evolved regarding the composition of the liquid eggs.

For eggs procured by the Army,[55] Navy, and Air Force, it is specified that whole eggs shall have eggs solids of not less than 26 percent, whites not less than 11.5, yolks not less than 43, frozen sugar yolks not less

than 38.7 and frozen salt yolks not less than 38.7 percent.

At the present time, there is considerable research work being done in an attempt to improve further the quality of frozen eggs.

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If you searched this chapter for something which was not found in it, please let the editors know.

7. PREPARATION OF FOOD PRODUCTS FOR HOME FREEZING

FREEZING will not improve the quality of a poor product. The principal factors which affect quality are: (1) selection of raw materials; (2) rapidity of handling; (3) methods of processing and preparation; (4) quality of packaging materials; (5) freezing method; (6) temperature and conditions of storage space.

Vegetables which are normally cooked give desirable frozen products, while those which are eaten when raw and crisp cannot be frozen successfully.[3,12,14,15] The first group includes peas, snap beans, lima beans, cut corn, broccoli, greens and the like. In the second are lettuce, celery, melons and similar vegetables.

Fruits, in general, yield good frozen foods.[15] They may be used as desserts or for pastry fillings, salads or jams. However, apples, pears, grapes and plums may be more practically preserved by other methods. Grapes are desirable when used for jelly or jam; apples for pastries, apple sauce and apple butter; pears for pear butter; and plums when stewed or in pastries.

In the selection of fruits and vegetables for freezing, variety and maturity are extremely important considerations.[3,12,14,15] Some varieties of fruits and vegetables possess certain characteristics such as color, flavor, firmness and texture which are maintained during processing, freezing and storing that others do not. Because of growing habits and climatic conditions, a variety which is suitable in one area is not always as suitable in others. Maturity has a decided bearing on the desirability of fruits and vegetables when frozen. A tough stringy, vegetable gives an inferior frozen product, while tender, succulent, healthy vegetables are savory and desirable when frozen. An overripe, spotted, mushy or a hard green fruit gives a displeasing, rather tasteless and often bitter product, while fruits selected at their proper maturity make superior frozen foods.

CLARENCE W. DUBOIS, Author Chapter 7. Born 10/16/09 in New Paltz, New York. Educated at Cornell University, BS, 1935. Formerly fruit and vegetable Inspector, N.Y.S. Dept. of Agriculture and Markets, Rochester, N.Y., 1935; Extension Service, N.Y.S. College of Agriculture, Ithaca, N.Y., 1936–38; Investigator, Chemistry Division, N.Y.S. Experiment Station, 1938–43; Associate Professor, Head of Dept. of Food Preservation, Louisiana State Agricultural Experiment Station, Baton Rouge, La., 1943–45; Consultant, D. K. Tressler and Associates, Westport, Conn., 1945–49. Minute Maid Corp., Plymouth, Florida, 1950 to date.

Author numerous contributions to trade and technical publications; Chaps. 7 and 35, 1946 Applications Volume, ASRE Data Books.

Member of Amer. Soc. of Refrig. Engrs. (Locker Committee, 1947–49); Inst. of Food Technologists (Regional Section Committee, 1944–45).

Preparation

Vegetables. The preparation methods employed require care and speed, in order to preserve color, flavor, texture and nutritive values during normal storage life. It is necessary to scald or blanch the vegetables prior to freezing to reduce to the minimum physical and chemical changes. Boiling water blanching should be carried out with at least 2 gal of water per pound of vegetable.[15] The water should be kept boiling by a good source of heat. A container with a flat bottom is best **(Table 1).**

In the home, hot water blanching is considered by many to be simpler and more reliable than steam blanching **(Fig. 1).** There has been some question as to the effectiveness of steam blanching in the home, as done by covered kettles, pressure saucepans, and vented pressure cookers. Colvin and Du Bois[2] have demonstrated that steam blanching requires an additional time for enzyme inactivation in blanching peas and mustard greens. One half pound of peas were sufficiently blanched only after 2.5 min in the pressure saucepan, while the temperature reached 249.8 F (121 C). Some of the peas on the outside of the sample were completely cooked while those in the interior were just sufficiently blanched.

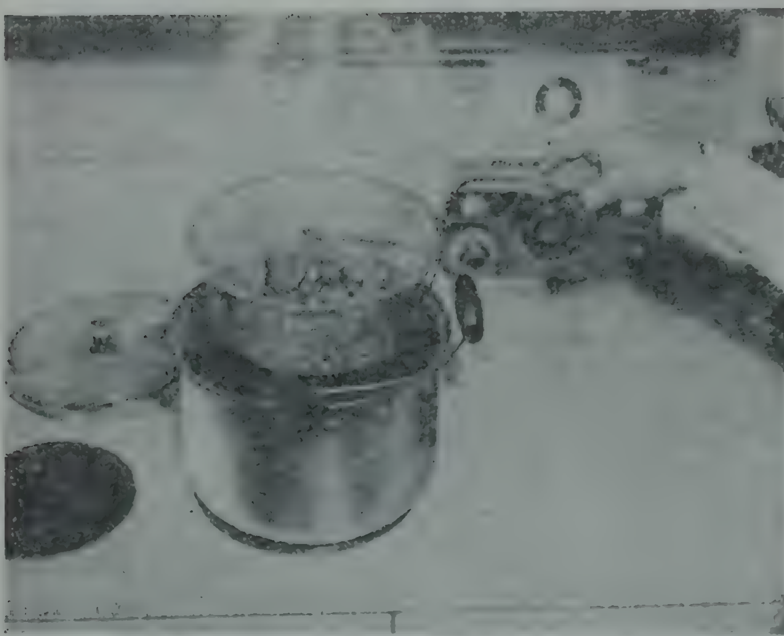


Fig. 1. A Method of Water Blanching.

It was also found that a 20-qt pressure cooker required more time than was generally recommended. It was necessary to steam 1 lb. of peas, equally distributed in a perforated pan, for 3.5 min. Similar results were found in blanching mustard greens (Table 2). When peas or mustard greens are immersed in boiling water it requires only 1 min. for proper blanching.

Unless high pressure steam is available and handled in the proper equipment, steam blanching[4] probably should not be undertaken with covered kettles, pressure saucepans, and pressure cookers. Even though more of the soluble vitamins and other constituents may be lost in blanching in boiling water,[1,20] it is faster, simpler, more reliable and positive in the home.

A few vegetables are completely cooked before they are frozen. Winter squash, tomatoes, beets and small whole potatoes are completely cooked in preparation for freezing. There is some question whether or not it is practical to freeze tomatoes and beets since the canned product is as good as the frozen and these vegetables must be thoroughly cooked, anyway, in preparation for freezing. It may be just as easy to can them and thus save storage space in the freezer for other products.

Fruits. A few fruits such as cranberries and blueberries may be frozen dry, that is, without sugar or syrup. Generally speaking however, the color, flavor and texture are best preserved by packing the prepared fruits in syrups or mixing them thoroughly with **sugar** until the sugar is dissolved[3,12,14,15,17,18,19] (See **Table 3**). Cane sugar gives the most satisfactory products. Unflavored corn syrups may be mixed with cane sugar or syrups in proportions of one part corn syrup to three parts cane sugar syrup. Fruits that are sliced or crushed are mixed with sugar at the rate of 1 lb of sugar to 4 lb of fruit. Rather than being mixed with dry sugar, sliced peaches, halved prunes, halved apricots and whole berries are packed in sugar syrup. Some authorities suggest 60 percent syrup solutions while others prefer a 40 percent syrup for fruits. Those who favor the lower concentration contend that unless sufficient time is allowed for penetration of sugar and the extraction of fruit juices to dilute the syrup, syrups of the higher concentration do not become hard frozen at 0 F and should there be a break in the container, the syrup and juice continually oozes from the package and spreads over other packages in storage.[21]

There are two causes for partially soft packages. In the first, the fruit is slowly frozen and the sugar and other soluble solids which as a result are concentrated at the center of the package remain unfrozen. The second is an improper proportion of syrup to fruit. If the 60 percent syrup does not exceed the proportion of 33 percent syrup to 67 percent fruit by weight and the products are frozen in a few hours, there is little danger of soft packages. The lower concentrations of syrup cause the fruit to be watery, soft, and less flavorful upon defrosting due to the greater per-

Table 1. Data on Preparation of Vegetables for Freezing

Vegetable	Variety best suited for freezing	Key**	Maturity desired	How to prepare	Scalding period (boiling water)
Asparagus	Mary Washington Martha Washington	E E	Tender tips best	Cut spears to 6 in. length	Small stalks: 3 min Large stalks: 4 min
Beans, green shell	French Horticultural	VG	Before pods dry	Shell	1 min
Beans, Lima, large seeded bush	Fordhook Burpee's Bush	E E	Green beans best	Shell	Med. beans: 1½ min Large beans: 2 min
Beans, Lima, large seeded pole	Challenger King of the Garden Giant Podded	VG VG VG	Green beans best	Shell	Med. beans: 1½ min Large beans: 2 min
Beans, Lima, small seeded bush	Clark's Dreer Bush Henderson Bush Baby Potato	E VG VG VG	Green beans best	Shell	Small beans: 1 min Med. beans: 1½ min
Beans, soy*	Giant Green Willomi Bansei Hokkaido	E E E	Green beans best	Scald pods, shell	2 min
Beans, snap or stringless, pole	Kentucky Wonder Blue Lake	E E	Small beans best	Snip, then cut into ¾-in. lengths	2 min
Beans, snap bush	Lowe's Champion Wisconsin Refugee	VG VG	Small beans best	Snip, then cut into ¾-in. lengths	2 min
Beets	Detroit Dark Red Crosby	E E	Young and tender	Cut off tops	1½ in. diam: 2½ min mature beets should be cooked, then rub off peels; slice
Beet greens	Any above variety	E	Young and tender	Eliminate all coarse large leaves	2 min
Broccoli	Italian Green Sprouting	E	Compact heads	Cut head into pieces not thicker than 1 in.	Small pieces: 3 min Med. pieces: 4 min Large pieces: 5 min
Brussels sprouts	Half Dwarf Improved Long Island Improved	VG VG	Dark green compact heads	Cut sprouts from main stem	4 min
Carrots	Nantes Coreless Amsterdam Coreless Red Cored Chantenay	E E VG	Young and small	Top, scrape then cut into ¼-in. slices	3 min
Cauliflower	Forbes, Snowball White Mountain Perfection	E E	Solid heads	Cut head into pieces not thicker than 1 in.	Small pieces: 3 min Med. pieces: 4 min
Chinese cabbage		E	Solid heads	Cut individual leaves from stem	1 min
Collards		VG	Small leaves best	Cut off and discard main stem	2 min
Egg plant†	Black Beauty Windsor	G G	Mature	Peel, slice in ⅓-in. slices	4 min
Kale	Tall Curled Scotch Dwarf Curled Scotch	F F	Young and tender	Cut off and discard main stem	70 sec
Kohlrabi	Early White Vienna	VG	Young and tender	Cut off tops, peel, dice in ½-in. cubes	1 min
Mushroom†	Cultivated (Agaricus Campestris)	E	Small size with white, tight caps	Cut off base of stem	Small size: 3 min Large size: 4 to 5 min
Mustard	Curly	F	Young and tender	Cut off and discard main stem	1 min
New Zealand Spinach		F	Young	Cut off and discard main stem	1 min
Okra††	Green Velvet	E	Tender pods	Cut away stems	Blanch pods 2½ min Cut following blanching if desired

Table 1 (Continued). Data on Preparation of Vegetables for Freezing

Vegetable	Variety best suited for freezing	Key**	Maturity desired	How to prepare	Scalding period (boiling water)
Peas	Dark Podded Thomas Laxton Thomas Laxton Shasta [1] (other varieties listed below)	E E E	Sweet and not starchy	Shell, discard starchy peas	Small peas: 45 sec Large peas: 60 sec
Peas†† (field peas)	Bluegoose Crowder	E E	Filled pods	Shell	1 min
Potatoes** Irish (cut for French frying)	Chippewa Katahdin Houma Bliss Triumph Smooth Rural	E E VG VG VG	1 month after digging	Peel, cut into ¼-in. sticks	2 min
Potatoes Irish (whole small)	Cf. above varieties	VG	Immediately after digging	Peel	1.5 in. size: 6 min 1.75 in. size: 8 min
Potatoes†† (sweet)	Porto Rico	VG	1 month after digging		Boil until done. Peel, mash
Pumpkin	Field	VG	Fall	Peel	Cook until done. Mash
Rhubarb	MacDonald Ruby Linnaeus	VG VG VG	Early spring best	Eliminate leaves; cut into 1-in. lengths	1.5 min
Spinach	Nobel Hollandia King of Denmark [2] (other varieties listed below)	E E E	Young	Cut and discard thick stems	2½ min
Squash, summer	Summer Crookneck	F	While tender, before rind hardens	Slice in ½-in. slices	3½ min
Squash, winter	Golden Delicious Golden Hubbard	E E	Fully mature, with hard rind	Peel, cut in 1-in. cubes	Cook until soft, mash
Sweet Corn, yellow	8-row Golden Bantam Golden Cross 10–14-row Golden Bantam [3] (other varieties listed below)	E E VG	(Method of preparation depends upon whether corn is left on cob or cut off)		
Sweet Corn, white	Crosby Hybrid (E-45-2) Country Gentlemen	F F	(Method of preparation depends upon whether corn is left on cob or cut off)		
Sweet Corn, on cob			Before starchiness develops	Husk, eliminate under- and overmature ears	Small ears: 6 min Med. ears: 8½ min Large ears: 10½ min
Sweet Corn, cut			Before starchiness develops	Scald on cob as directed above, cool, then cut off whole kernels	Small ears: 6 min Med. ears: 8½ min Large ears: 10½ min
Swiss Chard	Lucullus Fordhook Ruby	E VG VG	Small leaves best	Cut off and discard main stem	2 min
Turnips	Purple Top Strapleaf White Globe Purple Top Rutabagas	E E E	Young and tender	Cut off tops, peel, dice in ½-in. cubes	1 min
Turnip greens		VG	Young and tender	Eliminate all coarse large leaves	1 min

** Key to Preferred Varieties: E—Excellent; VG—Very Good; G—Good; F—Fair.

[1] Additional varieties of peas: Gradus, World's Record, Improved Gradus, Laxton's Progress, Glacier, Morse's Market, Stratagem (Potlach), Hundred Fold, Onward, Stridealong, Dwarf Alderman, Little Marvel, President Wilson, Banqueteer, Alderman or Telephone—all VG.

Asgrow 40, Laxton's Cropper, Teton, Laxtonian, Admiral Beatty—all G.

[2] Additional varieties of spinach: Viking, Virginia Savoy (fall spinach)—all E.

Old Dominion, Princess Juliana, Prickly Winter, Viroflay, Broad Flanders, Long Standing Bloomsdale—all VG. Victoria—G

[3] Additional varieties of yellow sweet corn: Purgold, Seneca Golden, T. C. Maine Bantam, Lincoln, Indigold, Aristogold Bantam—all VG.

Gemcross, T. C. Burbank Bantam, Tendergold, Early Bancross, Marcross, Whipcross—all G.

Table 1 (Continued). Data on Preparation of Vegetables for Freezing

Conclusion of notes for Table 1 (see preceding two pages).

† Cool first in 2 percent citric acid solution; then cold water.

* Taken from Progress Report of March, 1942; N.Y.S. Agricultural Experiment Station, D. K. Tressler and C. W. DuBois.

†† Unpublished data. Louisiana Agricultural Experiment Station, 1944, Food Preservation Department, C. W. DuBois. 0.06 g of citric acid or aconitic acid is mixed with 100 g of washed potatoes to preserve color, or 0.6 g to 2¼ lb of potatoes.

Unless otherwise indicated, all data in this table are taken from N.Y.S. Agricultural Experiment Station Bulletin 690, 1940. "Freezing and Storage of Foods in Freezing Cabinets and Locker Plants," by D. K. Tressler and C. W. DuBois.

centage of added water. The high concentrations are sometimes objected to as being too sweet.

Other Products

Juices and purées. Some fruit juices, such as apple juice, are excellent when frozen.[13] Purées from strawberries and black, red and purple raspberries give delightful frozen products to be used as ice cream toppings, flavorings for ices, for jelly making, or beverages. Tomato juice may be frozen, but the tomatoes must be heated to 180 F before extracting the juice and the juice sufficiently cooled for freezing. Certain components of the juice coagulate, however, during freezing and storage, making it rather undesirable. Commercially, it may be practical to concentrate juices partially before freezing, but this process may not be so desirable for home operations. Also, combinations of juices such as carrot, celery and tomato with seasoning might become popular with home freezers.

Table 2. Results of Steam Blanching in a Vented Pressure Cooker

Vegetable	Wt of sample, lb	Time of blanching, min	Final temp of product, °F	Presence of catalase activity, Positive or Negative
Peas	1	3	194	P
Peas	1	3.5	207	N
Peas	1	3.5	206	N
Peas	1	3.5	210	N
Mustard greens	½	2	177	P
Mustard greens	½	2.5	189	P
Mustard greens	½	3	192	N
Mustard greens	½	3	183	N
Mustard greens	1	2	175	P
Mustard greens	1	2	163	P
Mustard greens	1	2	173	P
Mustard greens	1	2.5	179	P
Mustard greens	1	3	187	N
Mustard greens	1	3	172	P
Mustard greens	1	3	190	P
Mustard greens	1	3	200	N
Mustard greens	1	3.5	204	N
Mustard greens	1	3.5	194	N
Mustard greens	1	3.5	192	N
Mustard greens	1	3.5	207	N

Meat. Although freezing does make meat slightly more tender, it will not perform the miracle of making tough, low-grade meat into tender, high-class meat. The original product must be of good quality. Methods of handling, proper chilling and cooling, aging, cutting, and packaging meat also play an important part in keeping quality during frozen storage. Sanitation of the equipment in slaughtering places, coolers and curing rooms is extremely important.

Meats are cut into meal-sized pieces, wrapped separately in moisture-vapor-proof materials. (See page 81–83 and Chap. 11.) When more than one piece of meat is placed in a package, the pieces can be separated easily when still frozen if a sheet of the wrapping material is placed between the cuts, as in **Fig. 2.**

Ground meats that are to be frozen and stored should contain no salt. Other seasonings may be included with favorable results. Salt added to ground pork stimulates the oxidation of the fats, causing them to become rancid quickly. On the other hand, seasonings such as pepper, sage and ginger have some protective action on the fats during storage.[8]

Fish. Fish are handled with the same care as meat.[14,15] Immediately after being caught, fish should be cleaned and iced. When the iced fish have been brought home, they are then packaged in moisture-vapor-proof wrapping and frozen.

Poultry. Chickens, ducks, turkeys and other poultry may be preserved success-

Table 3. Data on Preparation of Fruit for Freezing

Fruit	Variety	Method of preparation	Type of pack
Apples	Baldwin, Northern Spy, Winesap, Greening	Peel, slice in 12ths, blanch in water 90 sec., cool	Dry (no sugar or syrup)
Apricots	Blenheim, Moorpark, Royal, Tilton	Wash, cut in halves, pit	½ cup 60% syrup to 1 lb fruit
Blackberries or dewberries	Eldorado Lucretia	Clean, wash, eliminate red and green berries	½ cup 60% syrup to 1 lb fruit
Blueberries	Wild, New Jersey, Rubel, Cabot	Stem, wash, crush slightly	4 or 5 lb fruit to 1 lb sugar
Cherries, Sour	Montmorency, English Morello	Wash, chill, pit	4 lb fruit to 1 lb sugar
Cherries, Sweet	Lambert, Bing, Windsor, Black Tartarian	Stem, wash, pit	½ cup 60% syrup to 1 lb fruit
Cranberries	Early Black, Howe	Wash, stem, eliminate poor berries	Dry (no sugar nor syrup)
Currants	Red Lake, Perfection	Wash, stem, crush with sugar	4 lb berries to 1 lb sugar
Figs	Celeste, Brown Turkey, Mission, Kadota	Wash, stem	½ cup 60% syrup to 1 lb fruit*
Gooseberries		Stem, wash, crush slightly	4 lb berries to 1 lb sugar
Grapes	Thompson Seedless, Muscadine, Muscat	Stem and wash	½ cup 60% syrup to 1 lb fruit*
Grapefruit	Duncan, Marsh Seedless	Peel, section	½ cup 50% syrup to 1 lb fruit
Loganberries, Youngberries, Boysenberries		Clean, wash, eliminate under- and over-ripe fruit	½ cup 60% syrup to 1 lb fruit
Oranges	Valencia, Temple, Pineapple	Peel, section	½ cup 50% syrup to 1 lb fruit
Peaches	Hale, Hale Haven, Rio Oso Gem, Elberta	Peel, pit, slice	½ cup 60% syrup to 1 lb fruit*
Pears	Bartlett	Peel, core, quarter	½ cup 60% syrup to 1 lb fruit
Pineapples	Smooth Cayenne	Peel, remove core, slice or dice	½ cup 60% syrup to 1 lb fruit
Plums, Prunes	Italian prune, Damson, Stanley, Redwing	Wash, pit, quarter	½ cup 60% syrup to 1 lb fruit
Raspberries			
Red	Cuthbert, Viking, Chief, Milton, Newburgh, Latham	Clean, wash in ice water, eliminate immature berries, drain well	4 or 5 lb berries to 1 lb sugar
Black	Bristol, Cumberland, Evans		½ cup 60% syrup to 1 lb fruit
Purple	Sodus, Columbian		
Strawberries, sliced	Marshall, Klondike, Van Rouge, Blakemore, Big Late, Sparkle, Midland, Swanee	Wash in ice water, hull, cut in slices, ½-in. thick	4 or 5 lb berries to 1 lb sugar
Strawberries, whole		Wash in ice water, hull	½ cup 60% syrup to 1 lb fruit

Source in part, Bulletin 690, New York State Agricultural Experiment Station; "Freezing and Storage of Foods in Freezing Cabinets and Locker Plants," by D. K. Tressler and C. W. DuBois.

After the fruit and syrup have been placed in the carton, the fruit should be pressed down so that the syrup will rise to cover the fruit.

Sixty percent syrup is made by adding 3 lb 2 oz of granulated sugar to one quart of hot water, 40 percent by adding 1 lb 6 oz of sugar to a quart of water. The syrup should be cooled at least to room temperature before use. One cup of sugar weighs approximately ½ lb. Add Vitamin C to preserve color, twelve 200 mg tablets or one level teaspoonful of crystals per batch of syrup of size given above.

fully in farm and home freezers. Healthy, well-finished birds give the most satisfactory frozen product. Old birds are likely to be tough and less desirable. All birds should be completely dressed, ready to stuff or cook. This is done for several reasons; the most important are that (1) the birds can be drawn more easily before being frozen than when taken from frozen storage, (2) the flavor and quality is better preserved over a prolonged storage period up to 10 to 12 months at 0 F and (3) the birds are then ready for cooking when removed from the freezer thus saving time.

Some farm freezers may be used for marketing poultry, especially chickens and turkeys, on a commercial scale. Market birds must be handled with such care that their appearance is excellent; they are usually handled in volume to permit the use of special poultry handling equipment such as scalders with electrically controlled temperature, and rotary pickers. When the scalding is done by such equipment, birds are at the low temperature of 126–128 F and can be picked with ease by mechanical pickers.

When hand methods are used for small numbers of birds, the scalding temperatures are higher, usually at 160 to 170 F so that the feathers can be removed easily by

Fig. 2. Separation of Pieces of Meat with Wrapping Material.

hand. Scalding at such temperatures usually causes the skin to be rough and gives the bird a poor appearance.

Birds to be frozen at home are best drawn immediately after picking. They should then be washed in ice water to remove most of the animal heat. They may then be put up for the purpose for which they are to be used. Friers and fricassee birds are to be cut up, broilers are halved; birds to be roasted are left whole. The birds which are to be cut up may be wrapped in a moisture-vapor-proof wrapper or placed in cartons such as are used for vegetables and ground meats. The halves and whole birds should be wrapped tightly in moisture-vapor-proof material, air pockets being eliminated insofar as possible. It has been found that the use of stockinette or tightly pulled cheese cloth will hold the wrapping material tightly to the product.

Ducks and geese may also be scalded in the same manner as chickens and turkeys, but, after scalding, each duck or goose is wrapped in a burlap sack or a heavy cloth material to effect a thorough scald. Ducks and geese are then handled in the same manner as other poultry.

In some instances, it has been advocated that whole birds may be stuffed with a regular poultry stuffing before being frozen. No experimental data have been reported indicating the effects of such a procedure on the quality of frozen poultry. Inasmuch as salt rather quickly stimulates the rancidity in the fat of ground meats during frozen storage, salt may possibly affect the internal poultry fats in the same manner. Until more information is available, it seems advisable to omit the stuffing procedure from birds to be stored longer than two months at 0 F.

Cooked foods. There are a few vegetables that are best preserved for long periods by cooking before freezing. There also are other cooked foods such as hash, stews, chicken pie, and goulashes which are excellent when frozen. They can be kept with satisfaction for several months. For left-overs which would be used up within a short time, freezing is a practical solution to preserve them without spoilage longer than at household refrigerator temperatures. Baked cakes, breads and rolls, and unbaked pies can be stored frozen for several months to retain their freshness provided they are well packaged. Large tin containers with slip covers, in which the products are placed and stored have proved to be very satisfactory.

All cooked foods *must* be *cooled* quickly and thoroughly to at least 60 F. This is done for three reasons: (1) hot foods often melt the coatings from many packages and may overcook because of slow cooling in paper packages; (2) hot foods cause the freezer to run continuously by placing an extra and unnecessary load on the compressor; and (3) if a large load of hot foods are placed in a small freezer, there is danger of spoilage occurring. Where coated packages are used, cooling is done before packaging them. When certain metal packages are used, hot products may be cooled under running water after packaging.

Labeling packages. It has been found important to label each package clearly

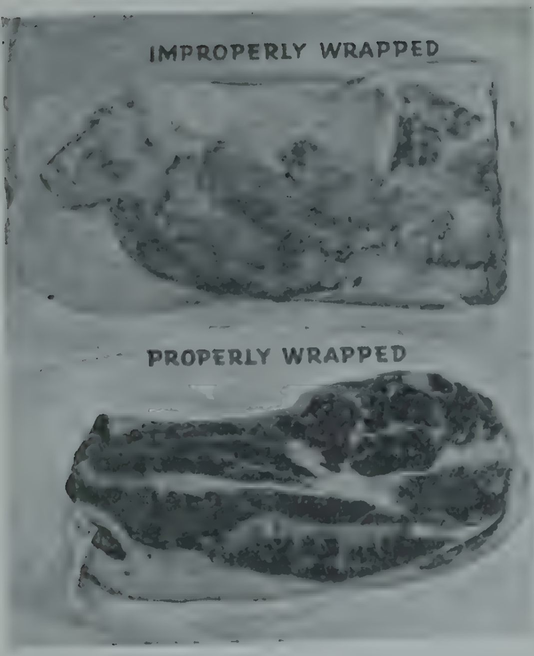


Fig. 3. Dehydration of Meats Due to Poor Wrapping.

and identify it with the name of product and the date when packed. When placing foods in storage it is important to arrange them in an orderly and systematic fashion so they can be easily located when desired. An inventory record showing the quantity of each food on hand and its location in the cabinet is helpful.

Packaging and Wrapping Materials

The air in farm and home freezers and locker rooms may have a rather low relative humidity.[15] Consequently, unless the foods are thoroughly protected, they will **dry out** rapidly **(Fig. 3)** and at the same time they may also take up abnormal flavors during storage.[6,7,15]

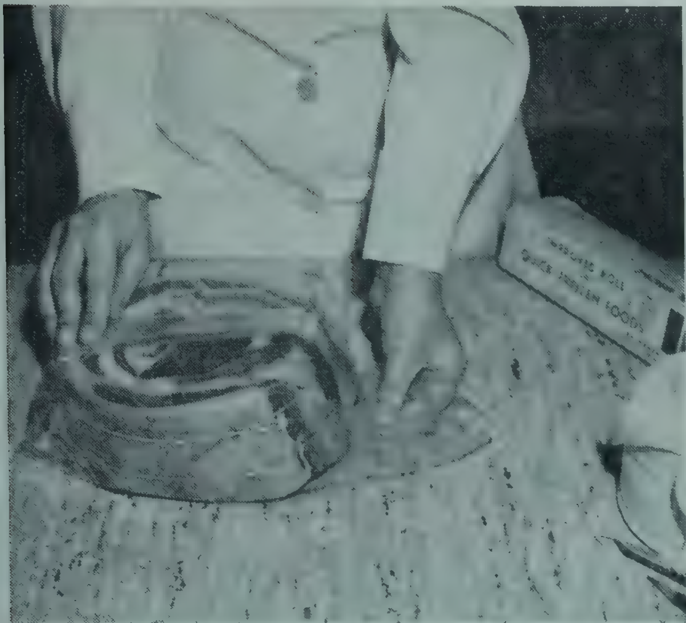
Numerous papers and wrapping materials are advertised and sold for protecting meats, poultry, fish and other products in storage. Many of these are better suited than others in protecting frozen foods. All materials offer some resistance to the passage of moisture-vapor, but some offer more resistance than others due to their character. In general, *moisture-vapor-proofness* is a term applied to a material with high resistance to the passage of moisture-vapor. Those materials which do not pass more than 1/28 oz per 100 sq in. per day at a relative humidity of 50 percent at 5 F have been found to be most desirable for packaging foods stored in farm and home freezers and in locker plants, provided that they do not otherwise deteriorate at low temperatures.[7,15,22] Careful selection of material is important. **Table 4** shows the various types of wrapping materials with ratings for frozen food packaging (see also **Chap. 11**).

Table 4. Types of Wrapping Materials with Ratings for Frozen Food Packaging

Type of packaging material	Moisture-vapor-proofness rating
Cellophane (moisture-proof anchored coating)	Excellent
Polyethylene	Excellent
Pliofilm	Excellent
Cry-o-wrap	Excellent
Saran	Excellent
Aluminum foil	Excellent
Double wrap locker paper (m.v.p. Cellophane and paper)	Excellent
Waxed paper coated one side	Fair to poor
Waxed paper coated two sides	Fair to poor
Special resin coated papers	Very good
Micro-wax coated papers	Fair to good
Waxed parchments	Fair
Plain papers and butcher paper	Very poor

The same moisture-vapor-proof protection that is necessary to protect cuts of meat against drying and flavor changes should prevail in packaging fruits and vegetables and ground meats to be stored frozen. There seems to be no perfect **carton,** each type having some disadvantage, and the acquisition of some skill in the use of all of them is required. There are some that are better adapted to certain products than to others; some can be used successfully for dry packing; some are better than others for irregularly shaped or lengthy products; some, because of shape, sacrifice space but seal well; others are rather difficult to fill and seal.

Round, heavily waxed containers with slip-in or slip-over covers are easily filled and sealed. Not all products pack well into them, however, and hot foods will melt the wax. Because of their shape, there is con-

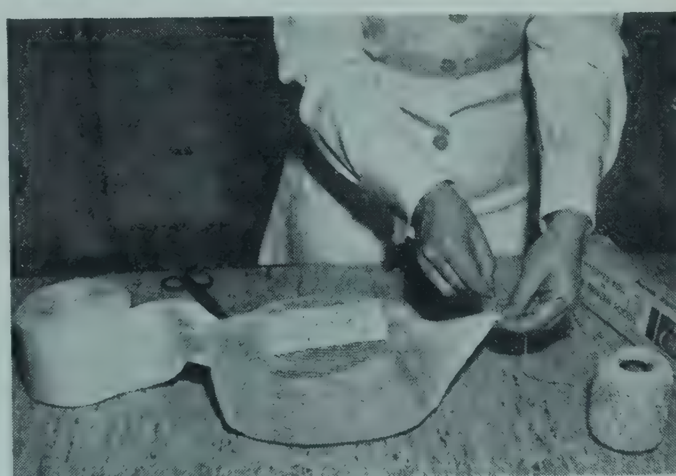


siderable loss in storage space as compared to the square-cornered types. Some of the square-cornered containers have bags or sheet liners made of moisture-vapor-proof materials. The bags are heat-sealed or twisted and tied at the top to make them liquid tight. Those having sheets glued to the inside can be used only for dry-packed foods and are well adapted to lengthy vegetables such as asparagus or broccoli. There also are square-cornered containers that do not require a liner and can be sealed and made liquid-tight by a tight-fitting cover.

There now are special glass containers made for packing foods for freezing. These are designed with tapered sides so that the products may be removed without complete defrosting. These containers may be used over many times. However, there is some breakage hazard involved in their use. Aluminum foil packages are also being made. They have the advantages of being quickly filled and being metal, allowing more rapid freezing than other containers. The aluminum containers are rather light weight, therefore, cannot be successfully used more than two times. Recently, there have been several types of plastic containers introduced. These packages have the advantage of being transparent, of ease of filling and closing, and of being unaffected by hot foods. Freezing is slower than with metal containers. Fig. 5 shows some of the newer types of packages.

Individual bags, without a carton to give them shape, are not practical for farm and home cabinets. They become irregular in shape when frozen; thus they waste storage space and are difficult to place in tiers to give orderly arrangement in the storage area. Typical containers now available are shown in **Fig. 6,** and methods of using one type are shown in **Fig. 7.**

Fig. 4. (Above and below.) How to Wrap Meats for Frozen Storage.



Freezing and Storage Temperatures

In the early development of freezing preservation, the public became prejudiced against "cold storage" or haphazard freezing of foods.[14] Later the term "quick freezing" was applied to foods where better methods were followed. Selection and maturity of product, speed in handling during processing, processing methods, packaging, and storage conditions are now recognized as part of the requirements of a good frozen product. As a result of the development of locker plants and farm and home freezers,

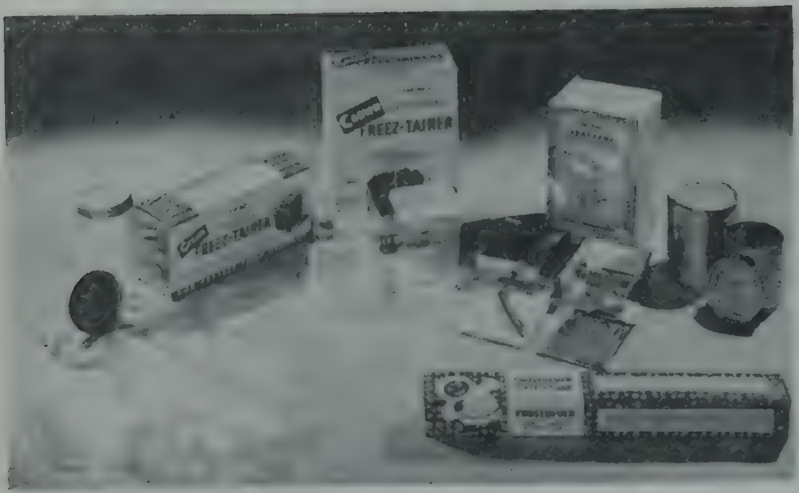


Fig. 5. Assortment of Recently Introduced Packaging Materials for Home Freezing.

Fig. 6. Typical Frozen Food Containers.
a. Cellophane bags
b. Rectangular waxed carton
c. Parchment bags with inner lining
d. Bag-in-box carton
e. Waxed paper cups
f. Cylindrical carton with waxed coating.

Fig. 7a. Packing Food in Containers for Freezing.

there has been some reversal in concept of "quick freezing" to the extent that there are advocates who wrongly feel that speed of freezing is of little consequence so long as a food eventually is frozen. A general rule to follow is to cool the product thoroughly and freeze as rapidly as possible.

The **time required** to freeze foods does not depend entirely on the temperature of the freezer alone but on the following factors: size and shape of package; the product being frozen; the arrangement in the freezer; the initial temperature of the product; the amount of food being frozen; the air circulation; whether or not the product is in direct contact with the evaporator; and whether the packages are spread out singly or packed solidly in freezer. All packages preferably should be relatively small. In a cabinet intended for gravity or forced air circulation methods of freezing, the packages should be spread out to allow free passage of air around them. Packages placed in chest-type cabinets designed for contact freezing should be placed against the side walls, leaving the center open. In vertical cabinets where shelves are freezing plates, freeze but one layer at a time (**Fig. 8**). In a cabinet that does not have a separate compartment for freezing, the packages of food to be frozen should be placed away from packages already frozen or separated from them by some suitable insulating material such as a thick layer of newspapers.

Fig. 8. Arrangement of Packages in Freezer.

It is accepted by authorities who have a broad experience in the field that packages of food should be frozen solidly in a **10-hr period** after being placed in the freezer to maintain the high quality and freshness in flavor. This can be done by conventional methods only in temperatures of 0 F, or lower.

Changes occur in foods during frozen storage. These changes, however, are not sudden nor marked. They occur gradually and are affected by conditions brought about by such factors as selection, preparation, packaging, freezing and storage of the products.

After a great deal of effort and care has been expended on the part of the user of a farm or home freezer to produce high quality products, the storage temperature is the determining factor of whether or not the **quality** is to be maintained during the desired time foods are stored frozen. Usually the user wishes to maintain a supply of each particular product over a period from one growing and harvest season to the following new season. Therefore, the storage conditions must be such that the quality can be maintained for a 1-yr period. Although some products may store better than others, there are such a number of different products frozen and stored that the storage section of a farm and home

Fig. 7b. Packing Food in Containers for Freezing.

freezer must be maintained as uniformly as possible at **0 F or below.**[3,15,19]

If the temperature is 0 F or below, most vegetables will keep their Vitamin C, bright color, and fresh flavor without noticeable change for a year.[5,6] Changes in asparagus and snap beans occur more quickly than in other vegetables.

In fruits, the color, flavor, and nutritive value can be maintained at 0 F for a year. The quality and flavor can be retained in most meats at a temperature of 0 F. If the temperature conditions are much higher, the fat of meat becomes rancid and the lean develops undesirable or "old" flavors in storage more rapidly. Beef that is aged at 32 to 34 F for five days can be stored at 0 F. successfully for one year. That which is aged longer cannot be stored successfully at this temperature for so long a period. Young poultry that is dressed directly after killing can be stored successfully for a year or more but mature birds can be stored only about 11 months without noticeable change. Game birds including turkey should not be stored over 6 months. Veal, lamb, and pork can be kept frozen at 0 F for 1 yr if these meats are frozen immediately after being thoroughly chilled. Ground beef from properly handled carcasses, if unsalted, can be stored successfully for one year. Sausage containing salt cannot be stored successfully for longer than three months.[8] However, if the salt is left out and other seasonings are included in ground pork to be frozen, the product will keep satisfactorily for eight months at 0 F.

Fatty fish such as mackerel, salmon, shad and trout will not remain free from foreign or off-flavors as long as lean fish such as haddock, cod, flounder and bass. Lean fish can usually be kept in good condition for 10 to 12 months stored at 0 F. Fatty fish can be stored in good condition for about 6 months at 0 F. However, if fatty fish are dipped in an ascorbic acid (vitamin C) solution of 0.05% strength for ½ minute, the storage period may be prolonged several months.

Handling Foods While Defrosting the Cabinet

Removal of frost from the coils or refrigerated surfaces is occasionally necessary for best operation of the cabinet and good maintenance of temperatures in the cabinet. For defrosting cabinet, see Chap. 38.

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If you searched this chapter for something which was not found in it, please let the editors know.

8. BACTERIOLOGY OF FROZEN FOODS

FROZEN foods, up to the present period, have not been subjected to the extensive bacteriological research accorded certain other food products. There are a number of reasons for this. Bacterial action is arrested by freezing. Most frozen foods are cooked before they are eaten; hence it has not been necessary to carry out the systematic bacteriological research requisite to certain other foods and to certain other methods of preservation. Also, frozen foods, especially those other than fish, are comparative newcomers to the food industries and there has not been time to develop, too well, the bacteriological aspects of such products.

By far the most prolific chapter dealing with the bacteriology of frozen foods has been written in connection with the effect of such products on the health of the consumer. It is hoped that, frozen foods having been established as safe foods, greater effort will now be extended to certain other phases of the bacteriology of freezing. It is not meant by this that the packer can afford to be less careful than he has been in the past, and it is assumed that the same or greater supervision will be given such products during their preparation.

Effects of Freezing and Storage

There is definite indication that bacteria, suspended in water, frozen, and stored at freezing temperatures, are soon killed. Sugar solutions, fats, etc., appear to exert some protective effect against the destructive action of freezing on microorganisms, and the speed with which the bacteria present on food products are destroyed during frozen storage is somewhat controversial.

Prescott, Bates and Highlands[17] made bacterial counts on a number of different types of foods frozen and held at −6.6 C (approximately 20 F) for different storage periods up to 12 weeks. With some foods, there was an indication of decreases in the number of viable bacteria, whereas with others there was no decrease. It is questionable whether any of the decreases obtained were significant.

Geer, Murray and Smith[9] obtained a decrease of more than 80 percent in the bacterial count of hamburg steak immediately after freezing and an average decrease of 84 per cent in the bacterial count of this material after a storage period of one month.

James[11] found that fats and sugars protect bacteria during frozen storage and concluded that the type of food and the type of microorganism determined the degree of survival.

Stuart[24] concluded that a temperature of −12 C (approx. 10 F) was necessary to prevent all bacterial growth in fish muscle.

Hanes[10] stated that more bacteria were destroyed by slow freezing and subsequent storage at relatively high frozen-storage temperatures than by fast freezing and subsequent storage at low temperatures.

Smart[23] obtained significant decreases in the bacterial count of frozen vegetables by freezing and storing in the frozen state for a period of 5 to 7 months.

McFarlane[13] found that there was a greater number of viable microorganisms in raspberries held at −20 C (−4 F) than in those held at −10 C (14 F) after a storage period of 24 weeks.

Unpublished work from certain laboratories has indicated that there may be an

JOHN T. R. NICKERSON, Author Chapter 8. Born 10/29/05, in Nova Scotia, Canada. Educated at Mass. Inst. of Technology, SB, 1932; MS 1934; PhD, 1938. Formerly Research Chemist, Birdseye Laboratories, 1937–40; Chief Chemist, 1940–45; Chief Chemist, Hygrade Food Prod. Corp., 1945–48; Research Chemist, Natl. Assn. Frozen Food Packers, 1948.

Author numerous articles on chemistry, bacteriology and technology of foods including fish, shellfish, and poultry; also on quality control and bacteriological methods.

Member of Inst. of Food Technologists; Amer. Chemical Society; Amer. Public Health Assn.

Now Research Associate, Dept. of Food Technology, Mass. Inst. of Technology, Cambridge, Mass.

apparent increase in the bacterial count of some meat products immediately after freezing. This is believed to be due to the breaking up of bacterial clumps.

Considering the fact that bacterial counts, by any method, are notoriously inaccurate, not because of the inefficiency of the workers who make such counts, but because of the nature of the counts themselves, nothing but general conclusions can be drawn regarding the effect of freezing on the viability of bacteria in food products. It is doubtless true that pathogenic bacteria tend to die off much faster than certain other types at storage temperatures used for frozen foods. After long periods of frozen storage there is probably a significant decrease in the number of viable bacteria in foods. It is questionable whether there is a decrease or an apparent increase in the number of viable bacteria in certain foods immediately after freezing, but it appears probable that there are no great decreases until the food has been subjected to some storage period at temperatures below freezing.

The higher frozen-storage temperatures appear to be more effective in destroying most bacteria than do very low storage temperatures.

Fats and sugar solutions probably have a protective influence on bacteria during frozen storage.

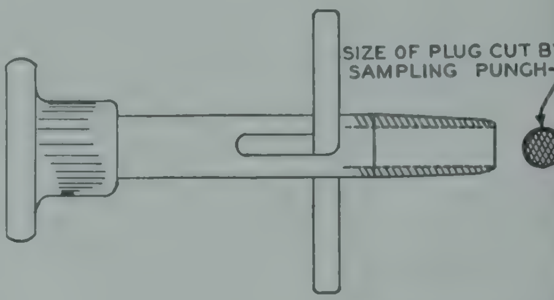
Berry[4] has shown that acid may have a decidedly bactericidal influence in storage although molds and spores apparently are affected to a lesser degree.

Methods of Making Bacterial Counts

In general the methods for bacterial counts on frozen foods are very similar to those used for other food products as described in "Standard Methods."[2] There are, however, certain features of the method which should be modified to obtain best results.

It is usually preferable to make the count on the product before the sample has been thawed. If the sample is thawed, the water frozen out with the product or remaining after processing, melts away. This water often contains larger numbers of microorganisms per unit weight than does the product itself, hence a representative portion of it should be included with the sample. Also, if the product is allowed to thaw, there is some danger of bacterial increases and, therefore, of obtaining a count which is not representative of the product itself.

In one laboratory a metal trocar is used for sampling the frozen product. This trocar removes a portion of definite area and of approximately uniform thickness. It is possible, with this method, to obtain nearly equal areas of most products per given weight. Besides this, it simplifies the sampling of frozen products and provides a means of obtaining specimens from a number of different portions of the product; see Fig. 1.



Tressler and Evers (28)

Fig. 1. Punch for Taking Sample of Fish or Meat for Bacterial Count.

Provided that the product is meat, fish or shellfish, it is believed preferable to grind it with a sterile meat grinder before using a definite weight (10 g in 90 ml or 11 g in 99 ml of sterile dilution water) for bacterial counts.

Better results are obtained with poultry by taking the sample on an area basis, since bacteria are mostly present either on skin surfaces or on the surface of the tissues lining the body cavity. This can be done by cutting out a definite area of the surface, cutting the portion into small pieces with sterile scissors and placing them in sterile dilution water. If it is desired to leave the product undamaged, a sterile swab may be used on a definite surface area, although this method is less accurate than the former.

An incubation temperature of 25 C

(77 F) has been found to give higher bacterial counts on frozen food products than either 20 C or 37 C. It has also been found necessary to incubate Petri dish cultures for a period of 72 hr when nutrient agar is used as a culture medium in order to obtain maximum counts.

Sanderson and Fitzgerald[21] found that a nutrient agar containing pablum and 0.5 percent of dextrose gave higher counts on frozen vegetables. There was also some indication that the incubation period could be shortened somewhat. This was apparently due to the fact that *Streptococcus fecalis*, an organism which they found to be associated with acid production and souring in quick frozen vegetables, developed faster on pablum agar. *Streptococcus fecalis* was found to be present in both fresh peas and corn examined aseptically.

One of the bad features of the bacterial count as a quality control measure is the long period necessary for incubation before the results of such tests can be obtained. Barkworth[3] and more recently Nickerson[15] have shown that a modified Frost Little plate method can be used in such a manner that the results may be obtained in 16 to 18 hr.

According to Nickerson, the following changes were made in the Frost Little plate method:

1. The incubation period was lengthened from 4–8 to 16–18 hr.
2. A new staining procedure was used.
3. A special slide was used to hold the culture.

The culture slide was provided with a central elevated portion of definite area which served as the surface supporting the culture (Fig. 2). This slide was made by grinding away the area around the central raised portion (now manufactured by the Scientific Glass Apparatus Company of Bloomfield, N. J.).

The slides were cleaned in dichromate-sulfuric acid cleaning solution, thoroughly rinsed, wiped dry and sterilized with dry heat in a closed metal container.

Small batches of nutrient agar (33.5 g of nutrient agar to 1000 ml of distilled water) were placed in homeopathic vials, the vials plugged with cotton and sterilized. When used, the vials were heated to melt the agar, cooled somewhat, and placed in a water bath held at, or near 113 F. The cotton plug was then replaced with a sterile rubber stopper fitted with a medicine dropper and bulb.

A sterile culture slide was placed on the warming table (metal plate regulated to 113 F by clamping on a ring stand above a hot plate) and 0.1 ml of the dilution water containing the product (10 g in 90 ml) was delivered to the raised portion of the slide. The measuring pipette used (capacity 0.1 ml) was lined several times by filling and emptying the pipette, and the lower portion wiped with a sterile cleansing tissue before the sample was delivered to the slide. Four drops of the nutrient agar were placed on the raised portion of the slide now containing the culture sample, and the material thereon was mixed. Mix-

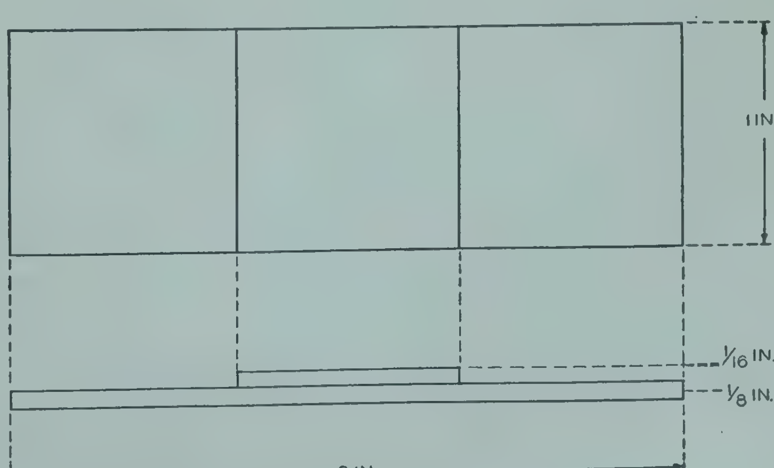


Fig. 2. Little Plate Slide.

ing was accomplished by running a sterile wire through the mixture 15 times, first backwards and forwards, then from left to right. The culture was spread to the edges of the raised portion by slanting the needle and following the edge of this area.

The cultures were incubated in a moist chamber from 16 to 18 hr at a temperature of 77 F, after which they were dried on a hotplate at about 176 F. They were then treated with a 1 percent aqueous ferric sulfate solution for 20 sec, washed slightly, and treated with a 0.5 percent solution of hematoxylin for 15 to 30 sec. The agar film was then washed and dried.

The prepared slide was examined microscopically, using a 16 mm objective, to detect bacterial colonies. The use of a blood cell counter greatly facilitated the microscopic work, since it was used to record both the number of fields and the number of colonies counted.

If 0.1 ml from the equivalent of 100 ml of dilution water, containing the bacteria from 10 g of product is used, the number of bacteria per gram of product is indicated by the formula:

$$100 \times \frac{\text{area of Little plate}}{\text{area of microscopic field}} \times \frac{\text{number of colonies}}{\text{number of fields counted}}$$

The total microscopic count shows great promise as a quality control test for frozen foods. This method was proposed by the committee on Microbiological Examination of Foods of the American Public Health Association.[30] The great advantage of this procedure for determining bacterial counts in foods is the speed with which the test may be carried out. A period of from 15 to 30 minutes is required for the completion of the various steps involved.

Because of the short time required to make microscopic counts such methods may, upon occasion, be used to check the sanitary quality of food products as they are being processed. It is also sometimes possible to use the microscopic count to grade the sanitary quality of the product, to cull out undesirable products and to provide for packaging according to sanitary grade.

There are certain limitations which must be considered when the total microscopic count is used for frozen food products. With this method both living and dead organisms are determined. The results, therefore, indicate what has happened to the product previous to processing in some cases. In other instances the care with which the product was handled during or after processing may be indicated in accordance with results of direct microscopic counts.

The data obtained with the microscopic count must be properly interpreted to give the best results. Technicians soon learn to interpret the results of counts of this kind when they become acquainted with the food products involved and with the methods of handling and processing to which these products are subjected.

The direct microscopic count may be less accurate than viable plate counts when material is examined which contains few bacteria. However, the microscopic method will indicate that the count is within a desirable range in such cases and this is adequate since no bacterial counts of any kind should be interpreted as an absolute number. There have been cases in which it has been shown that the culture media ordinarily used do not provide for the growth of certain types of bacteria which may be present in some food products in considerable numbers. Such organisms may be detected with the direct microscopic count.

The materials and equipment required for the carrying out of direct microscopic counts are as follows:

A blendor or mixer or Erlenmeyer flasks and stoppers for disintegrating the samples in water.

A number of Breed-Brew pipettes which are graduated to deliver 0.01 ml.

Slides—Etched guide plates having clear areas of 1 sq cm. give best results. These may be obtained in the 3″×1″ size.

A compound microscope with oil immersion objective. An ocular disc marked with a circle to limit the size of the field aids in counting in that it eliminates focussing during the examination of any field.

A counter—A blood cell counter, which provides for the recording of the total number of bacteria as well as the number of fields, is helpful.

Cleansing tissues for wiping the tips of pipettes.

A bacteriological needle and holder for distributing the sample.

Methyl alcohol for fixing the smear.

Xylol for de-fatting the smear.

Gray's Stain—Solution A—50 ml of a 1 percent aqueous solution of methylene blue—add 50 ml of methyl alcohol. Solution B—25 ml of a 1 percent aqueous solution of basic fuchsin—add 25 ml of methyl alcohol.

Mix solutions A and B.

Procedure for the direct microscopic count.

Standardize the microscope to determine the area of the field and the number of fields in an area of 1 sq cm.

Glassware should be clean but it need not be sterile.

Make a 1:2 dilution of the sample ~~and~~ in water and disintegrate the sample thoroughly.

Pipette 0.01 ml of the sample dilution into one of the unetched areas on a slide, wiping the outside of the pipette with cleansing tissue before delivering the diluted sample. Spread the specimen over the unetched area with a bacteriological needle. Dry the smear with heat.

Dip the smear in methyl alcohol, dry, dip in xylol and again dry.

Cover the smear with Gray's Stain for 30 seconds, wash and dry.

Examine the stained smear microscopically using an oil immersion objective. Record the total number of bacteria in 100 fields or in an adequate number of fields.

The microscopic count may be calculated by one of the following formulae:

If 100 fields are counted: 3 × total number of bacteria × number of fields in 1 sq cm.

If more or less than 100 fields are counted:

$$\frac{100 \times 3 \times \text{number of fields in 1 sq cm} \times \text{total number of bacteria counted}}{\text{number of fields counted}}$$

Significance of Bacterial Counts

It appears probable that too much emphasis has been placed on the bacterial count from the standpoint of its significance as a means of judging quality.

Wilson,[29] after conducting one of the few good researches concerning the accuracy and precision of bacterial counts, summed up his work as follows: "It is impossible to avoid the conclusion that the bacterial count is an inaccurate and unreliable method of ascertaining the number of organisms in milk. The final result, which even with a standard technique is correct only within limits—estimated at ±90 percent—bears no constant relationship to the total number of bacteria, either alive or dead, in the sample. As a figure, therefore, it possesses no special significance, and its value is purely relative."

Wilson's work was carried out on milk; therefore, the sampling error was probably not nearly so great as it would have been with certain other foods.

In the author's laboratory, it has been found that bacterial counts, repeated several times on different samples from the same package of frozen vegetables, vary enormously and that this variation is much greater with certain products than with others. The variation of any two counts made on two samples from the same package of frozen broccoli may be as great as 200 percent, even though an attempt be made to obtain comparable proportions of head and stalk in each sample.

Tressler[27] stated that provided the bacterial count of a frozen vegetable was below 100,000 per g, the following conclusions could be drawn:

1. The product was blanched at high temperatures.
2. The product had been quickly and adequately cooled.
3. The packing plant was sanitary.
4. The packaging material was clean.
5. The method of freezing was rapid.
6. The vegetable had not been thawed after freezing.

These conclusions are doubtless factual, since it would be quite certain that the absolute number of bacteria per gram in the product would not be larger than 300,000, even considering the great variation in precision, provided that a count of 100,000 had been obtained. An absolute

bacteria number of 300,000 per g would indicate a product of good quality.

It is questionable, however, whether a bacterial count of any magnitude should be set up as indicating a certain degree of quality for any frozen food product, since the only way to establish such a count as indicating the absolute number of organisms per gram in the food in question would be to make counts on a large number of samples from the same package and on samples from a number of packages from the same lot.

A bacterial count, therefore, like the organoleptic test, is only a general indication of the quality of any product; and interpretation of the results of such tests should be made only by those familiar with the product, and then only after proper consideration has been given to the inaccuracy of the methods used.

It has been the tendency of certain workers in the field to set up a low figure for bacterial count as a criterion of quality. This has had definite beneficial results since it has prompted quality control workers constantly to improve sanitary conditions in packing plants. However, it should again be pointed out that the bacterial count is not an accurate method of analysis and must be interpreted with proper care.

Types of Bacteria

Little work has been done on the types of bacteria which can be isolated from frozen foods. Smart[28] reported that yeasts, molds and soil types of bacteria were found to be present in frozen vegetables.

In the author's laboratory, the following bacterial genera have been isolated from frozen vegetables: *Flavobacterium*, *Vibrio*, *Bacillus*, *Cellulomonas*, *Phytomonas*, *Pseudomonas*, *Micrococcus*, *Streptococcus* (*fecalis*), *Mycobacterium*, *Staphylococcus*, *Leuconostoc*, *Achromobacter*, *Alcaligenes*, *Aerobacter*, *Erwinia*, and *Sarcina*. Yeasts, molds and several types of Actinomyces and Proactinomyces have also been found in frozen vegetables.

Public Health Aspects

Much of the bacteriological research on frozen foods has been concerned with the effect of these products on public health.

Certain groups of bacteria which cause gastro-intestinal diseases or gastro-intestinal disturbances or poisoning must be given proper consideration by food packers in the preparation of any edible product. Those organisms causing gastro-intestinal diseases are: The paratyphoid—Enteritidis group, the Dysentery group, the Alcaligenes groups and *Eberthella typhi*. Foods which are heat processed for long periods of time or those which will be well cooked before they are eaten will not be discussed here in detail, since with such products there is much less danger of transmitting these diseases. This is due mainly to the fact that the organisms involved will not survive the high temperatures of cooking or processing. It is assumed, however, that all food processors or handlers will take proper precautions in testing water supplies, and the like, to make sure products will not be polluted. Food products which may be eaten raw, such as certain molluscs or cooked crustacean products must, on the other hand, be handled with great care, since, if polluted, they may become the cause of much sickness.

It is probable that *Clostridium botulinum* is of greater importance considered from the standpoint of the effect of frozen foods on public health. This organism, though not pathogenic, may produce a toxin in foods which, when consumed, causes sickness and sometimes, death.

Gastro-intestinal disturbances due to the development of Staphylococci in food products will not be considered here, since the type of food products known to be involved are usually not frozen.

Prescott and Geer[20] reported that the spores of *Clostridium botulinum* may survive in food materials for at least 14 months at −16 C (approx. 3 F), and that the food became toxic in 3 to 4 days after thawing and holding at high temperatures. When stored at temperatures below 10 C (50 F), however, there was no production of toxin for at least 30 days.

Prescott and Tanner[18] found that frozen spinach which had been inoculated with detoxified spores of *Clostridium botulinum* thawed, and held at 10 C, did not contain toxin after 31 days at this temperature

Toxin was produced in 3 to 4 days at 20 C (68 F). The spinach, however, was definitely spoiled after this holding period. These authors found that foods containing organisms of the Salmonella group must be held at, or below, 5 C (41 F) after defrosting to prevent growth.

Experiments carried out by Prescott and Tanner[18] with *Eberthella typhi* indicated that 99 percent of such organisms were killed by freezing when suspended in water. They pointed out, however, that in the presence of food materials, survival of *Eberthella typhi* might be greatly increased. It was their opinion that available information indicated that there is little danger of typhoid from food which has been substantially frozen and stored for several weeks at 0 F.

Tanner[25] pointed out that the organism *Clostridium botulinum* is present in the soil of practically all states of this country and that freezing does not kill the spores. He noted that Berry[5] considered the possibility of botulism from the consumption of frozen foods to be very slight since, by the time that toxin had developed in such foods, they would have taken on such an appearance of decomposition that they would not be eaten. Tanner maintained that Berry's contention was not supported by facts, since canned foods which were badly spoiled have been known to be served.

Tanner, Beamer and Ricker[26] inoculated foods with detoxified spores of *Clostridium botulinum*, froze them for 3 hr, then held them at various temperatures for 4 to 14 days. Green beans, peas, asparagus, sausage, ground beef, cherries, peaches and black raspberries were the foods used. At 20 C (68 F) toxin was produced in 4 days in the nonacid foods. No toxin was produced in black raspberries or peaches even after 14 days, but toxin was present in the cherries after this incubation period. At 10 C (50 F) toxin was found to be present in peas and in ground beef after 14 days and in spinach after 4 days. No toxin developed in any of the foods held at 5 C (41 F).

These authors stated that, in general, detoxified spores of *Clostridium botulinum* may generate and produce toxin in refrigerated foods more alkaline than pH 4.5, which are stored at temperatures of 15 or 20 C. There was, they found, occasional production of toxin in nonacid foods stored at 10 C. No toxin was produced in 14 days in inoculated acid and nonacid foods stored at 5 C. They reported that *Penicillium* and *Mycoderma* might alter the pH above 4.5 in acid foods and thus allow toxin production.

These authors concluded that if properly handled and kept frozen until used, frozen foods are probably as safe and satisfactory as fresh foods. Their article pointed out that in all of their experiments large numbers of *Clostridium botulinum* spores were used, much larger numbers than would probably be found in the regular product.

Summarizing briefly the available information pertaining to the subject of frozen foods and their public health significance, it should be pointed out that it has been proved that such materials could be the cause of botulism if extremely badly handled. If such foods are properly **refrigerated after defrosting** (held at 41 F or below), there appears to be little or no danger of transmitting botulism through frozen foods. Even when improperly handled, it is evident that such food products must be badly spoiled before botulinum toxin develops; nevertheless, it has been pointed out that there is some possibility that such spoiled foods might be eaten if served. The spores of *Clostridium botulinum* appear not to be destroyed by freezing to any significant extent. The development of this organism in foods more acid than pH 4.5 is improbable, but sometimes made possible through changes in pH brought about by the growth of other organisms. According to Sanderson and Fitzgerald,[21] the danger of toxin production in frozen vegetables due to development of *Clostridium botulinum* is lessened by the growth of *Streptococcus fecalis*, an organism usually present which produces acid and changes the pH below the range which allows the toxigenic development of *Clostridium botulinum*.

The probability of transmitting gastrointestinal diseases through frozen food products is somewhat lessened because of the fact that the organisms involved are

fairly susceptible to freezing temperatures. However, proper care must be exercised to eliminate all possible sources of pollution, since it is known that there is some survival of such organisms for short periods of time during frozen storage.

The research dealing with public health aspects of frozen foods has been mostly carried out to show that frozen foods could have bad effects if improperly handled rather than to determine whether or not frozen foods are safe foods. Probably the best proof that frozen foods are safe and suitable edible products is indicated by the fact that no case of botulism has ever been traced to a regular frozen food product. As far as is known, no epidemics of any type have been definitely established as being caused by the consumption of frozen foods.

Sanitary Considerations

Since some frozen products may be eaten **raw** or without further cooking, it is necessary to use extreme care during processing and handling. Such foods are the shellfish, including clams and oysters, and cooked crustacean products such as shrimp and lobster.

Provided that shellfish products do not show positive tests for *Escherichia coli* or *Escherichia freundii* after freezing, it can be assumed that they are quite safe. Routine laboratory tests for these organisms should be made on all shellfish products of this kind. The directions for such tests may be obtained from "Bacteriological Examination of Shellfish and Shellfish Waters. Recommended Methods."[1]

In order to eliminate positive *coli* tests in shellfish products, certain sanitary rules must be observed in the packing plant. Some useful procedures are listed in the following:

All benches and tables should be **metal covered,** preferably with stainless steel, since this does not corrode and is much easier to clean. Galvanized iron may be substituted for stainless steel, but is not so satisfactory. Noncorrosive metal pans are preferable for handling or holding the product, but porcelain-covered metal may be used. All-metal knives and forks should be used for shucking; wooden handled implements are difficult to clean properly and should be avoided.

Waste materials should be held in metal containers. Refuse such as shells must be removed from the surroundings of the plant daily, and must not be allowed to accumulate, since it serves as a breeding ground for flies. In order to eliminate the contact of **flies** with the product, it is necessary that all entrances and windows of the plant be well screened. Flies may be the cause of pollution in shellfish products, since they can inoculate the product with intestinal organisms by contact. It is, therefore, very important to eliminate this source of contamination.

Pans, after cleaning, should not be nested, but handled in such a manner that they will drain and dry in a short time. The danger of contamination is lessened by this procedure. All implements and tables, etc., should be **cleaned** with a detergent and warm water, then rinsed with cold water at least twice daily. Whenever it is possible to carry out this procedure more often than twice daily, it should be done. After the final washing, it is well to treat equipment with a chlorine solution containing from 10 to 50 ppm of available chlorine or with a 1:500 solution of "Roccal."

The processing of **frozen vegetables** can be looked upon in a somewhat different light from the standpoint of public health. Such foods will be eaten only after they have been cooked; therefore, there is less danger from gastro-intestinal organisms.

The object of plant sanitation in this case is threefold: (1) To eliminate any source of pollution as through water supply; (2) to be sure that the organism *Clostridium botulinum*, if found in the neighboring soil, is present in the product in the smallest possible numbers; (3) to maintain a very low bacterial population in the finished product in order to prevent a loss of quality during certain phases of processing and later during defrosting.

Plant **water supplies,** used for processing, should be checked for purity by making periodic checks for the presence of organisms of the coli-aerogenes group. Procedures which will maintain low bacterial populations in the product will also tend to eliminate the spores of *Clostridium botulinum.*

Vegetables which are to be frozen should be transported to the plant and processed as soon as possible after harvesting. All products should be cleaned and washed thoroughly before they are blanched. Blanchers should be boiled out frequently to remove scale.

Quality separators must be washed, preferably with brushes, daily, since contamination from this source is frequent. Picking belts should be washed at least twice daily and scrubbed with brushes, using water and detergents at least once a day. Hoppers at the end of picking belts are often the source of bacterial build-up in the product and should be thoroughly cleaned, at least twice every day. Reels used to remove water should be cleaned frequently with brushes and water.

Flumes used for conveying the product through the plant should be thoroughly cleaned at the end of each day's operation. Buckets used for holding the product before packaging should be cleaned with hot water each time after they are used. Mechanical fillers must be washed with hot water, preferably also with detergents, at least twice daily.

Periodic bacterial count line-checks help to prevent bacterial increases in the product and serve to point out the sources of contamination.

Equipment used for processing should be made of metal wherever this is possible. Hoppers at the end of picking belts should be so constructed as to be easy to clean. Partly processed product should never be allowed to accumulate in large masses. For this reason, large hoppers over filling machines are to be avoided.

The accumulation of large amounts of partly processed product ahead of freezing machines, either packaged or unpackaged, should not be allowed, since such procedures always cause a loss of product quality.

Ensilage piles should be located at some distance from the plant since such material may become a breeding ground for flies and a source of such pests in the plant, despite the fact that, as previously recommended, all plant entrances and windows are screened to eliminate flies.

Bacteriological Research

Frozen vegetables, especially peas, lima beans, corn and asparagus, must be handled very rapidly after harvesting in order to prevent deteriorative changes. This fast processing of vegetables is even more important in the freezing than in the canning industry since off-flavors are more apparent in frozen than in canned products. Canned products are heat-treated and contain a certain amount of condiments, both of which tend to cover up the first signs of deterioration of quality which, in a frozen product, would be very evident. It is not meant to insinuate that canners process a low quality product, but rather to point out that the quality packer of frozen foods must be even more careful than the canned-foods packers.

Very little research has been carried out on methods of preventing bacterial increases in vegetables prior to processing in the plant. This should be a very fertile field for it is certain that loss of quality more often takes place at this point than at any other stage of handling.

Berry[6] found that enormous increases may take place in the bacterial content of raw peas between vining and processing at the plant. At the present time, little is done to prevent such losses of quality. Probably this has not been considered so important in the past because of the fact that blanching destroys most of the bacteria present in the product. Any frozen food packer knows, however, that regardless of what happens to microorganisms during processing, deteriorative changes brought about by their action beforehand largely remain with the product throughout.

Research carried out by the Canadian Fisheries Board on methods of handling fish has pointed to the use of sodium nitrite in ice, methods of cleaning bins used for holding fish, etc. This phase of fish marketing and freezing has long been recognized as most important. It is expected that future research in this field will be carried on with increasing intensity both from the standpoint of the use of bacterial inhibitors and with the object of better sanitary procedures for handling the product.

Research which deals with the prevention of deterioration in food quality prior to processing involves not only bacteriology but chemistry and engineering as well.

Some of the research problems include the development of more efficient non-toxic, bacterial inhibitors; better application of the agents available for such purposes; the working out and enforcement of better sanitary procedures for handling foods, etc. One of the chief requisites of the industry is the invention and application of mechanical apparatus which will provide for processing foods in such a manner as to eliminate bacterial contamination largely, or prevent bacterial increases during processing by eliminating surface moisture, or natural culture medium, which supports such increases. All of these problems and many more will, one day, be solved by workers in the field of food research. The field offers unlimited opportunities.

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If you searched this chapter for something which was not found in it, please let the editors know.

9. NUTRITIVE VALUE OF FROZEN FOODS

THE nutritive value of frozen foods is dependent on the raw material and on the methods of handling, processing, packaging, storing, cooking, and holding.

Comparative studies of the nutritive value of fresh and frozen foods indicate that the losses incurred during freezing procedures may be relatively small. Great care, however, all along the line from choice of seed, or other source of supply, to the dining table is necessary to make this statement true. For example, it was found in one series of tests that the ascorbic acid content of one brand of frozen green beans as they reached the kitchen averaged one-fourth that of another brand. The ascorbic acid content of one brand of frozen peas averaged less than half that of another brand. Even in one brand of frozen peas, the ascorbic acid in one lot was half that in another lot although all the packing cases of the peas had the same code numbers.[5] It is possible that the difference in ascorbic acid content of these peas was due to conditions in the factory previous to scalding of the vegetable or to differences in storage conditions.

The purpose of this chapter is to discuss the possible changes in the nutritive value of foods during (1) the time between the garden and the freezer, (2) freezing procedures, (3) storage, and (4) household and quantity cooking, holding, and rewarming of frozen foods.

Most of the studies made thus far have been concerned with the losses of vitamins from vegetables and fruits; little work has been done on the changes in protein, minerals, fats, and carbohydrates. Several recent studies have been made on the retention of the B vitamins in meats.

Before discussing losses, it might be well to recall the properties of each nutrient which explain how its losses may occur and, consequently, how they may be kept to a minimum.

FAITH FENTON, Author Chapter 9. Born in Zearing, Iowa. Educated at Iowa State College, BS; Columbia University, MS, 1923; University of Chicago, PhD, 1938. Formerly Teacher Public Schools, Iowa; Iowa State College 1925 (summer); Inst. Home Econ., Cornell University, 1922–25; Asst. Prof. 1925–41; Assoc. Prof. 1941–43; Prof. (Teaching and Research) 1943; Research Consultant on Frozen Foods, Univ. of Hawaii, 1949; National Chairman, Committee on Cooking and Processing Procedures, U. S. Experiment Stations Cooperative Project, "Conservation of the Nutritive Value of Foods," 1942–45.

Author of numerous articles in scientific journals on retention of nutritive value and palatability during freezing, dehydration, canning, and home-and-institutional-scale cooking of vegetables, fruits and meats; cooked and ready to cook frozen foods. Author Chap. 9, 1946. Applications Volume, ASRE Data Books.

Member of Sigma Xi; Phi Kappa Phi; AAASF; Inst. Food Technologists; Amer. Home Econ. Assn.; Chairman, NYS Div. Research Committee, 1944; Secretary, Food and Nut Div., 1946–48; Chairman, Research Dept., 1950; N.Y. Acad. Science; Assn. of Univ. Prof.; Omicron Nu; Sigma Delta Epsilon; and Pi Lambda Theta.

Received Alumni Merit Award, Iowa State College, 1947; Army and Navy Certificate of Appreciation, 1948.

Now Professor of Food and Nutrition, College of Home Economics, Cornell University, Ithaca, N.Y.

Nutritive Values Susceptible to Change

Ascorbic acid (**vitamin C**) is the nutrient which is lost to the greatest extent. Its retention is often taken as a criterion of the retention of quality in frozen foods, because if it is retained other health-giving elements, and palatability, are also likely to be retained.[66] It is lost both by destruction and by solution. Its manner of destruction is by oxidation. Therefore, on exposure to the air, ascorbic acid reacts with the oxygen present and is thus destroyed. Oxidation is hastened by heat, whether it be in a warm room where the fresh vegetables are held previous to freezing, or a long slow scalding period, or a raised storage temperature, or in the early stages of cooking. Oxidation is also hastened by enzymes which are active in all vegetables until they are sufficiently scalded. Light is also a factor in its destruction, as are certain heavy metals, particularly copper. Ascorbic acid is the most soluble of all known vitamins.

Vitamin B. The B-group, including thiamine (B_1), riboflavin (B_2), niacin, folic acid, pantothenic acid and pyridoxine, is said to be destroyed in the presence of heat and to be soluble in water. Riboflavin is particularly susceptible to destruction by light.

Vitamin A. Most of the vitamin A value is in the form of the yellow pigment, carotene. Carotene is readily destroyed by oxidation, especially at elevated temperatures, and in the presence of light. It is not soluble in water but is soluble in fat. It is more susceptible to destruction in the presence of rancid fat.

Table 1. Effect of Scalding Period on Loss of Ascorbic Acid

Vegetable	Time of scalding, sec	Loss of ascorbic acid, percent	Reference number
Beans, Lima $\frac{1}{2}$–$\frac{5}{8}$ in.	45	23	65
	60	27	
	75	32	
	150	40	
Peas	60	14	32
	85	22	
	128	30	
	153	34	

The **minerals** in foods are subject to only one loss, that of solution. Their availability for use by the body may be affected by freezing procedures and storage.

Proteins. Some of the proteins are soluble in cold water, and their availability for use by the body may be changed by freezing.

Fats. Most fats in food may become rancid by oxidation and hydrolysis, particularly at elevated temperatures, and over relatively long storage periods.

Carbohydrates. In living plant tissues sugars may be lost due to respiration of the living tissue, in which they are changed to carbon dioxide and water. Elevated temperatures hasten this change. Many carbohydrates, especially sugars, are soluble in water. Hydrolysis of starches to dextrins and sugars may occur, as well as hydrolysis of sucrose to the simpler sugars. Sugars may also be synthesized to starches by enzymes as a sign of advancing maturity.

From Garden to Freezer

It is to be hoped that every freezing plant—commercial, community or home—has control of the source of supply so as to insure the nutritive quality and palatability of the original food as it is grown, and also the time of its delivery to the plant. This applies especially to vegetables.

Many of the possible changes during the holding of fresh vegetables apparently occur most rapidly during the first 24 hr of storage and more rapidly at ordinary room temperature, but are kept to a minimum at refrigeration temperatures. Sugar is lost chiefly due to respiration,[36] and probably somewhat to changes to starch. This loss of sweetness is very obvious in such vegetables as peas and sweet corn. The crude fiber content and toughness of the vegetables is often increased on standing in a warm room,[22] and, consequently, the cooking time necessary to make them tender is also increased. Ascorbic acid is rapidly lost at ordinary room temperatures. Snap beans held on the receiving floor over a warm night lost more than half of their ascorbic acid,[45] as did peas[18] during shipping lasting from 24 to 48 hr. During storage for 24 hr at room temperature in crates, asparagus lost 40 percent and spinach 29 percent of their ascorbic acid.[23]

No loss of thiamine from fresh peas and corn was observed when they were allowed to stand as long as 5 hr at room temperature,[8] nor was there any observable loss of thiamine from asparagus and spinach when they were allowed to stand for as long a period as 24 hr at room temperature.[23] The asparagus, however, showed a loss of riboflavin of 22 percent and the spinach 5 percent. A probable explanation of the difference was the amount of light reaching the two vegetables and also the protective action of the chlorophyll in the darker-green vegetable. Garden-fresh and market spinach from different sources were found to have approximately the same values for thiamine and riboflavin although the former contained considerably more ascorbic acid.[8] Therefore, it seems that the loss of thiamin may be small in short periods of standing; that the loss of riboflavin is probably de-

Table 2. Loss of Vitamins During Freezing

Vegetable	Method: Scalding	Method: Chilling	Loss, percent: Ascorbic acid	Loss, percent: Thiamin	Loss, percent: Riboflavin	Loss, percent: Carotene	Reference number
Asparagus	Steam, 3 min	Spray, 3–4 min	24	28	42	24	23
			—	16–20	—	—	51
			—	22	5	—	17
			—	—	—	0	69
			—	—	—	0	19
Beans, green	Boiling water, 2 min	Cold water dip	33	0	0	—	16
	Boiling water, 2 min	Cold water dip	13	11	14	—	54
Beans, Lima	—	—	30	—	—	—	65
	—	—	—	26–54	16	—	17
	—	—	—	—	0	—	57
	—	—	—	—	—	0	69
Broccoli	—	—	19–40	—	—	—	35
	—	—	—	—	—	0	70
Corn, sweet	—	—	0	—	—	—	15
	Steam	Cold water dip	—	18–28	—	—	3
Peas	Boiling water, 1 min	—	38	—	—	—	20
	Boiling water	Running water	30	—	—	—	33
	—	—	30–37	—	—	—	64
	Boiling water, 1 min	Cold water dip	—	14–29	—	—	3
	—	—	—	2–7	—	—	51
	—	—	—	0	—	—	21
	—	—	—	3	—	—	17
	—	—	—	0	0	—	57
	—	—	—	0	—	—	17
	—	—	—	—	—	18	60
Spinach	Steam, $1\frac{3}{4}$ min	Counter-current water bath	63	51	40	13	23
	—	—	—	6	9	—	17
	—	—	—	—	—	0	69
	—	—	—	—	—	25	9
	Boiling water	Cold water dip	49	—	—	—	12

pendent on exposure to light, but that the ascorbic acid losses are rapid unless the vegetable is refrigerated. Losses of folic acid from chard, snapbeans and New Zealand spinach were found to be large when these vegetables were held at room temperature.[53]

Strawberries, blueberries, blackberries, dewberries, and raspberries, if free from injury when picked, and if held under refrigeration and without bruising, do not lose an appreciable amount of their ascorbic acid in 48 to 72 hr. Even if they are held at room temperature under market conditions for 1 or 2 days, there is little loss of this vitamin.[41] Similar findings for strawberries were also reported.[46]

In the following discussion, losses will be given in percentages rather than in actual content because the nutritive value of any processed food is greatly dependent upon that of the original fresh food.

Changes During Freezing

During freezing procedures, losses of ascorbic acid range from practically nothing in sweet corn (blanched on the cob) to 63 percent in spinach **(Table 2)**. In the former vegetable the tough hull forms a protective coating; in the spinach there is a high percentage of surface exposed both to oxidation and to solution. In any one kind of frozen vegetable as it reaches the kitchen there may be a wide range in

Table 3. Loss of Vitamins at Several Stages During Freezing

Vegetable	Stage in freezing procedures	Loss, percent			Reference number
		Ascorbic acid	Thiamin	Riboflavin	
Beans, green[1]	After 2-min boiling-water blanch	13	11	14	54
	Before packaging	19	17	18	
	After freezing	19	17	18	
Peas	After boiling-water blanch	10	7		32 and 51
	After quality separation	25	17		
	Before packaging	30	22		
	After freezing	30	22		

[1] Home-frozen.

ascorbic acid content. The ascorbic acid content of frozen peas from different lots varied from 5 mg[5] to 26 mg[62] per 100 g. Tressler[66] has given the normal value of frozen peas as 18 mg per 100 g. This content is verified by an inspection of the data on frozen peas from several laboratories over a period of years.

The greatest chances of losses during freezing procedures are in scalding and in the subsequent chilling (Table 3).

All vegetables are scalded previous to freezing in order to inactivate the enzymes present. Scalding kills the tissues, drives out the air, and stops respiration more or less completely. It partially sets the green color and prevents the development of "off" flavors and odors.

Vegetables contain enzymes, as previously mentioned, which accelerate the loss of ascorbic acid and of carotene, and possibly other vitamins. If the enzymes are not inactivated they will result in losses, not only during freezing, but also during storage (Table 4), during thawing, and during the first part of the cooking procedure.

Data indicate that losses of water-

Table 4. Effect of Preliminary Scalding on Ascorbic Acid, Thiamin and Riboflavin in Green Beans and Spinach

Vegetable	Treatment of vegetable	Loss, percent							
		Ascorbic acid		Thiamin		Riboflavin		Carotene	
		Newly frozen	After 1-yr storage at −4 F	Newly frozen	After 1-yr storage at −4 F	Newly frozen	After 1-yr storage at −4 F	After storage at −4 F	
								6 mo	11 mo
Green beans[1]	Scalded in boiling water, 2 min., cooled by cold water dip	33	47	—[2]	22	—[2]	3		
	Unscalded	75	90	39	74	24	39		
Spinach[3]	Giant variety								
	Scalded							5	36
	Not scalded							48	70
	King of Denmark								
	Scalded							7	49
	Not scalded							37	68

[1] Farrell and Fellers.
[2] Used as basis for calculating losses.
[3] Zscheile, Beadle, and Kraybill.

soluble vitamins during scalding vary from almost nothing to 40 percent and that the losses for most vegetables may be kept down by proper scalding methods to a maximum of about 15 percent.

A number of laboratories have compared the effect of scalding in steam with scalding in boiling water on the ascorbic acid content. A steam blanch of 5 min resulted in a greater retention of ascorbic acid in green beans than did a hot-water blanch of 3 min. Peas scalded in steam, and frozen on trays without cooling in water, retained more ascorbic acid than those blanched by scalding in water at 212 F for the same period followed by cooling in water.[63] Spinach scalded in boiling water for 2 min lost 49 percent of its ascorbic acid, about 12 percent of its thiamine, and 6 percent of its riboflavin; spinach from the same lot scalded in steam for 3 min, lost 41 percent of the ascorbic acid, and no observable amount of thiamin or riboflavin. The high loss of ascorbic acid probably occurs because of the slow rate of heat penetration in steaming due to the "matting" together of the leaves.[12] There is a marked trend in this country toward scalding vegetables by steam previous to freezing, dehydrating, or canning, rather than by water.

Excessively long scalding, especially boiling-water scalding, results in increased losses of ascorbic acid (Table 1) and other water-soluble constituents.

Balls[1] emphasizes the importance of realizing that enzymes, which are proteins, often, even though they are destroyed by heat, reappear on cooling due to reversion of the heat-denatured enzyme to its original active form. He states, "It seems as though the enzyme requires a high temperature to knock it apart but that the pieces are relatively vulnerable at lower temperatures." Perhaps the suggestion of Tressler that vegetables be blanched with superheated steam should be followed, and then the vegetables be subjected to a lower temperature. This phase of scalding requires more study with particular application to storage and thawing losses of ascorbic acid and carotene.

In some foods there is also a question of whether a scald sufficient for complete arrest of enzyme activity would not give a product of less desirable quality.

Using waters of pH values up to 8 in scalding peas and green beans resulted in very little effect on the ascorbic acid retention.[37] This finding may be due to the buffer action of these vegetables.

Because increasing the period of scalding increases the loss of water-soluble constituents, and because the oxidation of ascorbic acid occurs more rapidly at high temperatures, the action is stopped immediately by one of three methods: plunging in cold water or using a cold water spray or an air blast. Although excess contact with water in scalding, cooling, and sorting tends to leech out soluble materials, it is exceedingly important that the heating and the subsequent chilling be rapid. The water for chilling should be 50 F or below, and should be sufficient in amount to chill the vegetables quickly. It is possible to use smaller amounts of water when ice is added. If vegetables are not chilled to 50 F or below before they are packaged, there is great danger of loss of ascorbic acid and spoilage before they are actually frozen. In a 30 percent loss of ascorbic acid from peas, 10 percent occurred during scalding and most of the rest during the subsequent spray-cooling and sorting, similarly in a 22 percent loss of thiamin from the same vegetable, 7 percent occurred during scalding and most of the rest during the chilling and sorting (Table 3). The method of cooling is also important. Cooling blanched vegetables by cold air blast resulted in one-fourth less loss of ascorbic acid than cooling them in water.[7] Steam blanching followed by air cooling resulted in less loss of soluble solids than other methods.[28] If water blanching was used, little advantage was gained by air cooling. Even though some losses do occur during the blanching and chilling of vegetables they are not so great as those occurring without these procedures (Table 4).

Blanching of five vegetables by dielectric heating resulted in complete retention of ascorbic acid.[55] Proper cooling following blanching by dielectric heating presents some problems.

No losses of ascorbic acid during the actual freezing of scalded vegetables have been found.[20,31]

The rate of freezing had no effect on the

retention of ascorbic acid, thiamine, and carotene in asparagus, spinach, whole kernel corn and lima beans.[38]

Most fruits at the present time are frozen without preliminary blanching and cooling.

Whole and sliced fruits are usually covered with sugar or a **sugar syrup** to minimize oxidative action due to enzymes, and consequent loss of ascorbic acid. Orange juice lost no ascorbic acid during freezing.[6] Red raspberries of four varieties frozen without added sugar lost 19 to 24 percent of their ascorbic acid during freezing and storage,[64] and strawberries of two varieties which were packed in a dry-sugar pack and also in a sugar-syrup pack lost 10 to 20 percent of their ascorbic acid.[46] In neither study was it reported whether the loss was due to oxidation or to solution in the ice crystals which separated. Some of the raspberries were frozen after the addition of sugar; this appeared to have some protective action on the ascorbic acid. Recent studies report no loss from properly handled strawberries and raspberries during freezing alone.[42,43] The rate of freezing apparently does not affect the loss.[39] The protective effect of ascorbic acid and sulfiting which are often used to prevent darkening in light-colored fruits will be discussed later.

At present apples are blanched more often than not and this is done in steam; sliced cling peaches are also blanched. The losses of soluble solids during blanching are greater from fruits than from vegetables largely because of the high sugar content, lower insoluble-solids content and the softness of the tissue. Apples lost 13 percent of their soluble solids during blanching.[28]

It is customary to chill the hot fruit with cold water sprays or by conveying it through a tank of cold water for preliminary cooling and following this by fluming in water for 150 to 200 feet. Severe leaching losses occur during the cooling of the blanched fruit. Air cooling resulted in less loss of soluble solids than water cooling.[7] Apples which lost 13 percent of the soluble solids during blanching suffered further losses of 5 percent during a five minute spray cooling and 1.4 percent during the subsequent fluming.[28]

Thiamine and riboflavin are lost to some extent from vegetables during **freezing** procedures. This loss, which ranged from 0 to 54 percent of the thiamine, and from 0 to 42 percent of the riboflavin (Table 2), appears to be due chiefly to solution during scalding and subsequent chilling of the vegetables (Table 3).

A recent study[39] reports that freezing made little difference in the thiamine, riboflavin, niacin, pantothenic acid and pyridoxine content of beef or pork. This was true whether the meat was frozen very slowly or very rapidly.

Another laboratory reported that freezing had no effect on the thiamine content of lamb.

Some lack of agreement appears on the loss of carotene during freezing procedures. The more recent studies have shown some losses (Table 2). Since neither carotene nor vitamin A is water-soluble any loss is probably small. Some increases of carotene have been reported.

Minerals. Little work has been reported on possible losses of minerals during the freezing of foods. It is probable that solution losses of minerals would occur during the blanching and subsequent water cooling of vegetables. The total iron content of several quick frozen foods examined, including frozen asparagus, broccoli, sweet corn, lima beans, snap beans, peas, spinach, strawberries, chicken, and haddock, was somewhat lower than that of the fresh foods.[27] The availability of the iron for use by the body was, however, about 20 percent greater than that of the fresh foods. Techniques which help prevent solution losses of ascorbic acid and the B group of vitamins, will also prevent loss of minerals.

Protein. Relatively few, and no recent studies have been reported on the effect of freezing on the protein of foods. No effect on the nutritive values of the protein of blue and sand crabs,[68] of fresh milk or of evaporated milk,[44,52] have been observed during freezing.

Fats. No changes in fats during freezing procedures have been reported.

Carbohydrates. Any losses of carbohydrates during freezing procedures would probably be due to solution of sugars and

starches during scalding and chilling of vegetables.

From studies reported thus far it may be concluded that the losses which must be guarded against during freezing procedures are oxidation losses of ascorbic acid and carotene, and solution losses of ascorbic acid, thiamine, and riboflavin, and probably the other B vitamins, all of which are water-soluble. Care may also be required to prevent solution losses of carbohydrates and minerals.

Changes During Storage

If frozen vegetables have been scalded sufficiently (Table 4) and are stored at low enough temperatures, the vitamin content is retained fairly well in most cases (Table 5). The importance of maintaining zero storage temperature or lower in ascorbic acid retention is well illustrated by the work of Jenkins, Tressler, Moyer and McIntosh,[33] who stored asparagus, cauliflower, Brussels sprouts, yellow wax beans and Kentucky Wonder beans at −40, −20.2, 0.4, +10.4, and +15.8 F and determined their ascorbic acid content from time to time during storage from 6 to 10 months (Figs. 1 to 5). Jenkins, Tressler, and Fitzgerald,[32] after studying storage losses of ascorbic acid from broccoli, lima beans, snap beans, sweet corn, peas and spinach, reported "if the vitamin C content is to be conserved the maximum storage temperature permissible is 0 F." Broccoli stored for 6 months at 0 F contained twice as much ascorbic acid as did that from the same lot stored at 15 F.[24] Frozen peas and green beans stored for 12 months at 0 F contained about twice the ascorbic acid content of those stored at 10 F or those stored at fluctuating temperatures between 0 and 20 F.[26] From these figures a lesson on the destructive effect of allowing vegetables to thaw and then refreezing them, can also be drawn.

A recent study[33] on the vitamin content of four laboratory-frozen vegetables stored at 0 F for six months indicates the following losses, wet weight basis: *Ascorbic acid*, 20 to 33 percent from asparagus, 40 to 57 percent from spinach, 10 to 40 percent from whole kernel corn, and 0 to 11 percent from lima beans; *thiamine*, slight increases in asparagus, 25 to 40 percent loss from spinach and no loss from corn and lima beans; *carotene*, an increase in two lots of asparagus and a decrease in two other lots, a gain of 6 percent to a loss of 13 percent from spinach, and an increase in both the whole kernel corn and the lima beans. The same workers reported no loss of thiamine, riboflavin or carotene from frozen peas stored at −6 F for 6 months.

Another laboratory[4] reported that storage at 0 F for 12 months resulted in ascorbic acid losses as follows: steam-blanched peas 14 percent; broccoli 17 and asparagus 10 percent.

Losses of ascorbic acid during 12 months freezer storage of brine-packed okra were twice those of dry-packed okra.[29]

Raw apple juice to which ascorbic acid had been added prior to freezing retained two-thirds of the ascorbic acid after over two years of freezer storage at −6 F. Inactivating the enzymes by pasteurization resulted in complete retention of the ascorbic acid after 1.3 years of storage.[40]

Most of the studies on fruits have been concerned with storage temperatures of 0 F (Table 5).

The protective effect of sugar was shown in the following studies. During a two months storage period sweetened strawberries lost less than 5 percent of their ascorbic acid while unsweetened berries lost almost three times that amount. Unsweetened purees lost twice as much ascorbic acid as did the sweetened purees during freezing, 16 months storage, and defrosting.[42]

Peaches packed in 40 percent syrup retained after one year's storage at 0 F slightly over one-half of their ascorbic acid. With the addition of ascorbic acid to the syrup, the retention was increased to almost three-fourths, and with sulfiting to two-thirds.[58]

The effect of the temperature of storage on frozen strawberries was reported in one study.[26] Commercially frozen berries, which were stored for one year at 0 F and thawed, lost one-third of their ascorbic acid while those stored at 10 F, or at fluctuating temperatures between 0 and 20 F, lost twice that amount.

Frozen sweetened and unsweetened

Table 5. Losses of Vitamins During Storage

Vegetable or fruit	Storage: Temperature F	Storage: Time months	Loss, percent: Ascorbic acid	Loss, percent: Thiamine	Loss, percent: Riboflavin	Loss, percent: Carotene	Reference number
Asparagus	0	6	—	—	—	40	69
Beans, green	−4	12	47	22	3	—	16
Beans, Lima	0	11	—	—	—	11	69
Broccoli	0	5	—	—	—	0	69
	0 to −10	5	0	—	—	—	2
Corn, sweet	−7 to −10	12	—	0	—	—	3
Peas	−8	5	—	0	—	—	51
	0	11	0	—	—	—	47
	−7 to −10	12	—	0	—	—	3
	0	11	—	—	—	7–26	60
Spinach	0	5	—	—	—	0	69
	0	3	—	—	—	0	9
	−4	6	—	—	—	37–48	70
	−4	11	—	—	—	68–70	70
Orange juice	−15	-20	0	—	—	—	5
Cranberries							
Whole	0	9	0	—	—	—	30
Sliced	0	9	0	—	—	—	30
Crushed	0	9	0	—	—	—	30
Strawberries							
Sliced in dry sugar pack	0 to −10	4	50	—	—	—	46
		6	70	—	—	—	46
Whole in sugar syrup	0 to −10	4	50	—	—	—	46
		6	70	—	—	—	46
Peaches							
In sugar syrup	−10	6	—	—	—	0	10
Pulp with sugar	−10	6	—	—	—	0	10
Pulp without sugar	−10	6	—	—	—	0	10
Raspberries, red							
With sugar	0	9	19–24[1]	—	—	—	64
Without sugar	0	9	Slightly less than above	—	—	—	64

[1] On dry basis.

raspberries stored at 10 F lost no appreciable ascorbic acid in 4 months and not more than one-fourth of their content in $2\frac{1}{4}$ years.[43]

The period of storage is also important in storage losses of vitamins (Tables 4 and 5). Losses of carotene from frozen spinach stored at 4 F were small during the first

six months but were appreciable after 12 months, much greater after two years.[70]

The thiamine content of frozen pork was found to remain about the same after one year's storage at 0, 10 or at fluctuating temperatures between 0 and 20 F.[26] In a recent study the losses of thiamine, riboflavin, niacin, pantothenic acid and pyridoxine from beef and pork were slight after six months and were not affected by freezing rate.[39]

Cured frozen hams that had been stored for 4 months lost no thiamine or riboflavin but 15 to 20 percent of the niacin.[56]

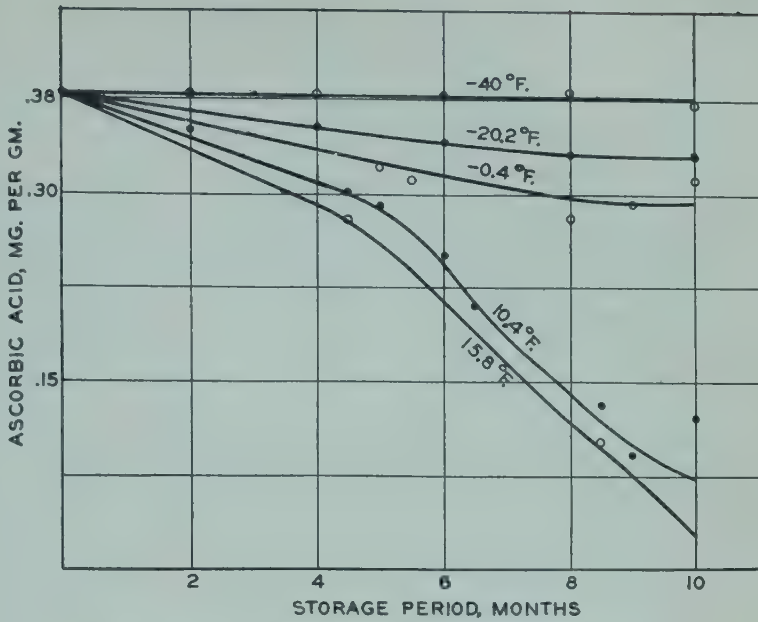

Fig. 1. Loss of Ascorbic Acid in Frozen Asparagus.

The higher the storage temperature, the sooner the fat becomes rancid due to oxidation and hydrolysis, and objectionable flavors develop in the meat. Oxidized fat does not have the nutritive value of sweet fat. Furthermore, there is increased destruction of vitamin A due to the presence of rancid fat. Pork fat, which is the most sensitive, became rancid in 2 months at 15 F and in 4 months at 10 F; at 0 F there was no rancidity at the end of a year.[13] Beef, lamb and pork were more stable but showed signs of rancidity in 3 months at 15 F and in 5 months at 10 F.

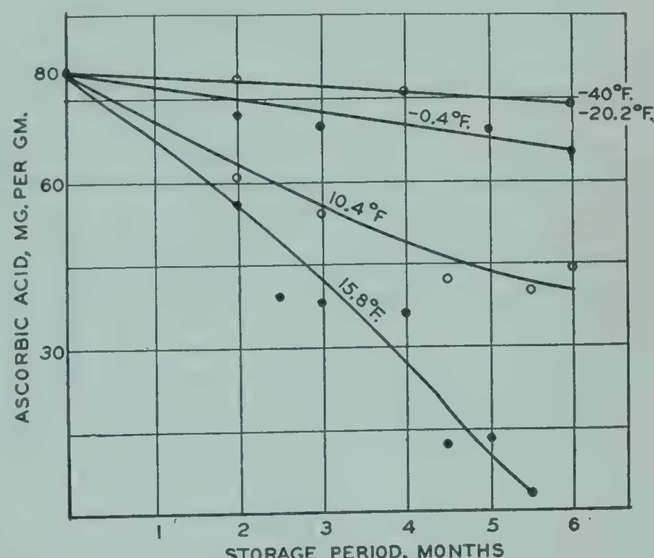

Fig. 2. Loss of Ascorbic Acid in Frozen Brussels Sprouts.

Tarrant, Kauffman and Ziegler[61] give the maximum holding periods of meat and add that it is more satisfactory to limit the storage period to one-half the maximum period shown in the following table:

Maximum Holding Period, Mos.

Kind of Meat	*At −10 F*	*At 0 F*	*Kind of Meat*	*At −10 F*	*At 0 F*
Pork	12	8	Veal	12	8
Beef	18	12	Poultry and game	12	8
Lamb	18	12			

The fat of fish becomes rancid more quickly than that of meat.

Proper storage, both as to temperature

and time, can prevent any appreciable change in the nutritive value of fats.[13]

DuBois and Tressler[14] found that the addition of salt activated the oxidation of fat in ground meats, but that pepper, sage, mace and ginger seemed to have some antioxidant effect on the fat during storage.

During storage of frozen fruits there is a gradual change of sucrose to dextrose and levulose. This does not affect the nutritive value, but it does make some sugars of the frozen fruits more quickly digestible than those of fresh fruits.

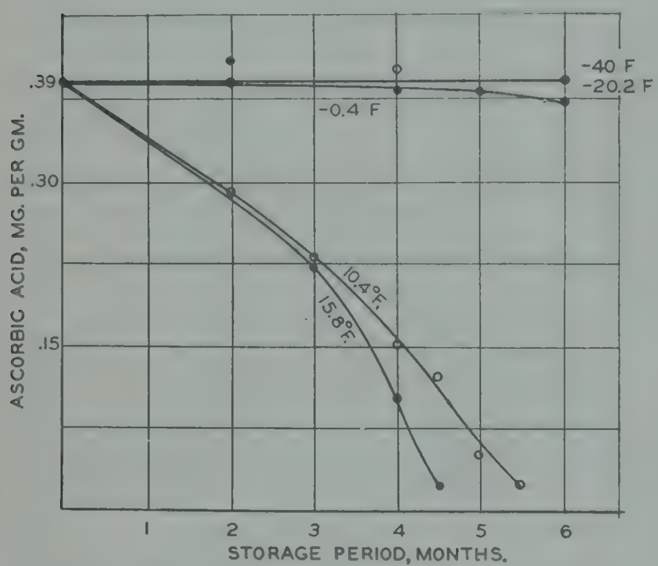

Fig. 3. Loss of Ascorbic Acid in Frozen Cauliflower.

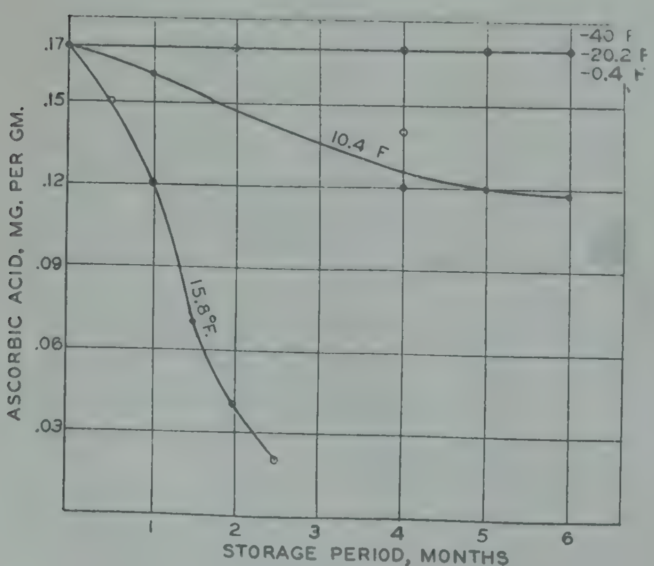

Fig. 4. Loss of Ascorbic Acid in Frozen Yellow Wax Beans.

Defrosting

That defrosting and refreezing of foods is harmful to quality and nutritive value is well known. Defrosting and refreezing destroyed practically all of the ascorbic acid present in high-bush blueberries.[41] To determine the effect of fluctuating storage temperatures several frozen foods were stored at 0, 10, and 20 F and also in a box having a frequent cycling of the temperature between 0 and 20 F.[26] It was found that storage at 10 F and storage at the cycling temperatures had about the same effect on the rancidification of pork, the loss of ascorbic acid from strawberries, beans and peas, and on the drop in palatability including drying out of all of these foods. Storage at 0 F resulted in better retention of quality in each food.

The nutrient which is most likely to be lost during partial thawing, complete thawing, and holding after thawing, is ascorbic acid. The influence of thawing on this vitamin will depend on several factors: (1) the efficiency of the scalding in destroying oxidative enzymes; (2) perhaps the degree of reversion of the heat-denatured enzymes; (3) the temperature of the vegetables at the beginning of the thawing period; (4) the period of thawing; (5) the temperature the vegetable is allowed to reach; (6) whether the vegetable is left covered in its original container or is exposed to the air.

No loss of ascorbic acid from frozen peas allowed to stand at room temperature for 24 hr in the closed original containers was observed;[31] nor was there appreciable loss from frozen peas when they were held in the closed original container at room temperature

for from 1 to 5 hr, or in a refrigerator (40 F) for 16 hr.[20] The latter peas had been blanched for 60 sec in boiling water or for 120 sec in steam. The frozen peas were removed directly from storage at −40 F and were not completely thawed when tested. Frozen peas which had been blanched 40 sec in steam lost 70 percent of their ascorbic acid when they were thawed from 2 to 6 hr.[18] None of the details of the thawing method was given. One study was reported on losses of ascorbic acid after thawing of the vegetable. When frozen peas that had been scalded for 2 min at 190.4 F were thawed by being allowed to stand in their hermetically sealed cans at 89.6 to 95 F for 2 hr, and then were removed from the containers and allowed to stand at room temperature, losses in ascorbic acid were as follows: At room temperature (70 F), in 30 min, 16 percent; in 1 hr, 27 percent; and in refrigerator (40 F) in 24 hr, 25 percent.[62] The amount of surface area of the thawed peas exposed to the air during standing was not given, nor were the losses during thawing in the hermetically sealed container.

Frozen broccoli which was allowed to stand in closed packages at room temperature for 1½ hr, and in a refrigerator (40 F) for 4 hr after removal from storage at 0 F, lost no appreciable amount of ascorbic acid. At the end of these holding periods the broccoli was thawed only sufficiently to allow for breaking apart of the stalks. This was done to allow for more uniform cooking of this vegetable, particularly in the pressure saucepan.[2]

Partially defrosting green beans in their original covered package at room temperature for 3 hr increased the temperature of the beans in the center of the package from a range of 16 to 26.5 F to a range of 32 to 43 F.[54]

Fruits are the only frozen foods which are customarily thawed and not cooked before they are served. Usually some ice is left in them. Fruits for pies are thawed only sufficiently to permit spreading them in the lower crust of the pie. Fruits used in cooking as in jellies and jams do not require thawing.

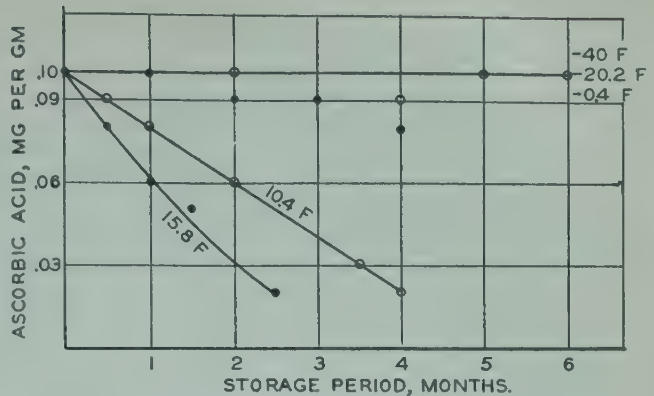

Fig. 5. Loss of Ascorbic Acid in Frozen Green Beans.

Only a slight loss of ascorbic acid occurred during the defrosting of frozen strawberries and raspberries when the defrosting was done in 24 hours at 35 F. When the defrosted berries were held in the refrigerator, the added sugar exerted a protective effect on the ascorbic acid.[42,43]

During defrosting, and holding after defrosting, the ascorbic acid tends to become equally distributed in the syrup and in the drained berries.

Meat may be thawed prior to cooking or it may be cooked from the solidly frozen state. No loss of thiamine, riboflavin or niacin occurred during thawing of frozen ground pork patties either at room temperature or under cold running water.[25] The frozen patties contained an average of 0.50 mg of thiamine, 0.19 mg riboflavin and 2.64 mgs niacin per 100 grams. These values were as high as any of those found in the literature for unfrozen ground pork.

Changes During Cooking

Regardless of the amount of nutritive value retained by the commercial or home processor, certain nutrients, particularly some of the vitamins, may be lost during the cooking of the foods. In fact, the nutritive value of the food as it comes to the table is as dependent on the treatment it receives in the kitchen as on that which it has received previously.

Most of the studies published thus far on losses of nutritive value during the cooking of frozen foods have been concerned with vegetables.

The cooking of frozen vegetables does

not present so many problems as does the cooking of fresh vegetables. The green colors of vegetables have been set by scalding and freezing; some of the acids and other components aiding in the development of "off" flavors and odors have been leached out during scalding and chilling. The enzymes have been completely or partially inactivated and, therefore, are not so destructive of ascorbic acid during the first few minutes of cooking as they are in fresh vegetables.

The fact that the vegetables have been partially precooked seems often to be a drawback because both the housewife and the chef often overcook frozen foods. They require only one-half to two-thirds the cooking time of the corresponding fresh vegetables with the exception of soy beans.

Household cooking. The factor that affects the retention of the water-soluble vitamins in household cookery the most is the amount of cooking water used (Table 6). As the amount of water is increased, the solution of vitamins is likewise increased. The amount of water required

Table 6. Effect of Increasing Cooking Water on the Retention of Vitamins in Frozen Vegetables

Frozen vegetable	Amount		Ascorbic acid		Thiamin		Riboflavin		Carotene	Reference no.
	Veg., g	Water, g	Drained veg., %	Cooking water, %	Drained veg., %	Cooking water, %	Drained veg., %	Cooking water, %	Drained veg., %	
Household cooking										
Asparagus	300	60	84	17	86	18	85	11	82	23
	—	1200	63	29	74	33	83	18	62	
Beans, green	300	50	73	17	82	—	86	—	—	54
	—	250	52	32	65	31	72	33	—	
Broccoli	300	0 (steamer)	80	11	—	—	—	—	—	2
	—	100	82	10	—	—	—	—	—	
	—	500	57	32	—	—	—	—	—	
	—	1000	53	37	—	—	—	—	—	
	300	50	82	14	—	—	—	—	—	34
	—	100	70	18	—	—	—	—	—	
	—	125	66	17	—	—	—	—	—	
Corn, sweet	300	100	—	—	78	22	—	—	—	3
	—	600	—	—	63	34	—	—	—	
Peas	350	0 (steamer)	45–55	17–22	—	—	—	—	—	47
	—	120	43–49	18–39	—	—	—	—	—	
	—	350	34–41	37–39	—	—	—	—	—	
	40–50	20	—	—	85–93	—	—	—	—	21
	300	50	—	—	82	21	—	—	—	3
	—	100	—	—	72	28	—	—	—	
	—	600	—	—	64	34	—	—	—	
Spinach	300	60	67	10	94	5	94	8	108	23
		600	49	40	61	39	67	32	93	
Quantity cooking										
	lb.	qt.	—	—	—	—	—	—	—	
Broccoli	5	0 (steamer)	87	—	83	—	86	—	—	34
	—	5 (steamer)	59	—	56	46	70	54	—	
	—	8 (steam-jacketed kettle)	61	—	56	—	56	—	—	

Table 7. Vitamins in Frozen Vegetables Cooked by Different Methods

Vegetables and method	Retention in drained vegetable: Ascorbic acid, %	Retention in drained vegetable: Thiamin, %	Reference number
Asparagus			
Boiled	80–92[2]		35
Pressure saucepan	73		
Broccoli			
Boiled	52–88		35
Pressure saucepan	82		35
Broccoli			
Boiled	53–82[2]		2
Steamer A[1]	79		47
Steamer B	80		
Pressure saucepan	76–80		
Brussels sprouts			
Boiled	77		47
Steamer A[1]	98		47
Steamer B	89		47
Pressure saucepan	97		47
Cauliflower			
Boiled	81		47
Steamer A[1]	83		47
Steamer B	71		47
Pressure saucepan	92		47
Lima beans			
Boiled	62		47
Pressure saucepan	75		47
Pressure cooker	64		47
Peas			
Boiled	70		47
Steamer A[1]	68		47
Steamer B	68		47
Pressure saucepan	88		47
Spinach			
Boiled	70		47
Steamer A[1]	73		47
Steamer B	71		47
Pressure saucepan	80		47
Corn			
Boiled		63–78[2]	3
Peas			
Boiled		64–82[2]	3

[1] Steamer A was a non-leach type of steamer.
[2] Depending on amount of cooking water.

will depend not only on the particular vegetable and the time it requires to cook, but the amount of the vegetable and its initial temperature, the initial temperature of the water, the composition, capacity and diameter of the pan, whether the pan is covered or uncovered, the rate of heating, and the actual cooking time. The amount of water recommended on the commercial package must of necessity be ample to prevent burning; often the housewife can decrease it. Particular care is necessary when cooking several packages of frozen vegetables at one time, not to multiply the amount of cooking water for one package by the number of packages used. The effect on the water-soluble constituents is especially marked up to the amount of water which completely submerges the vegetable. Increasing the amounts of water beyond this point seems to have relatively little effect. The extent of the effect even up to this point is greatly affected by the surface area of the vegetable exposed and the nature of the particular vegetable studied.

Because the frost of frozen vegetables is high in the water-soluble vitamins, it should become a part of the cooking water. The weight of the frost in a 12-ounce package of commercially frozen broccoli ranged from 10 to 30 g and contained from 18 to 30 mg of ascorbic acid per 100 g.[2]

Fortunately, it is possible to secure palatable products with a small amount of cooking water, even with the green and the so-called strong-juiced vegetables, after they have been frozen. They may also be acceptably cooked in covered or uncovered pans for the same reasons. Some may be steamed.

As previously stated, the most common error in cooking frozen vegetables is to cook them too long (Table 8). Overcooking results in increased losses of ascorbic acid and of palatability but not of thiamine, riboflavin or niacin. Frozen broccoli cooked 2 min after the water returned to the boil, which required 5½ min, retained 64 per cent of its ascorbic acid; after 5½ min, 57 percent; and after 11 min, 55 percent.[2]

Cooking frozen vegetables in pans of different composition, or cooking with the cover off or on the pan, had no appreciable effect on the retention or destruction of ascorbic acid during boiling.[48,2]

The type of equipment made little difference in the retention of vitamins in frozen vegetables in studies in our laboratory. With the final amount of cooking water kept constant the retentions were about the same in frozen peas whether they were cooked in a stew pan or by dielectric heat.[59]

During cooking of frozen peas in home

amounts (4 servings) in our laboratory, the retention of ascorbic acid in the drained peas ranged from 73 to 95 percent, thiamine retention from 85 to 103, riboflavin from 85 to 100 percent and no loss of carotene occurred. The ranges of retentions in lima beans were: ascorbic acid from 80 to 97 percent and thiamine from 86 to 103 percent.

Large quantity cooking. In the quantity cooking of frozen broccoli the method in which the ascorbic acid, thiamine and riboflavin were best retained was that in which no water was added—steaming.[34] The retention of each vitamin in the other five methods was about the same **(Table 8).** The effect of the amount of cooking water on the vitamin retention is not so great in large quantity as in household cookery, because when large amounts are cooked by most methods, the vegetable must of necessity be covered or almost covered with water, in order that the vegetables around the edges not be burned before the center is heated. This is particularly true in the steam-jacketed kettle where the heat is more intense than in ordinary boiling. The trend, however, is to use less water in large scale cooking whenever possible.

It is possible, even in quantity cooking, to retain relatively large amounts of the several vitamins in the drained, cooked vegetables (Table 8); the percentage retentions of ascorbic acid in the frozen broccoli cooked in quantity were about the same as in that cooked in household amounts.

In a study of losses of ascorbic acid, thiamine and riboflavin from peas, green beans, and lima beans during cooking of lots of 100 to 300 lb in steam-jacketed kettles, considerable reduction in the ascorbic acid values was observed. Much less reduction in the thiamine and riboflavin values occurred under these circumstances.[5]

Indications are that frozen meat is subject to about the same losses of vitamins during cooking as fresh meat. Frozen ground pork patties retained about 84 percent of the thiamine, 96 percent of the riboflavin and 97 percent of the niacin whether they were pan broiled, oven-broiled or cooked by dielectric heat.[25] Small amounts of the vitamins were found in the drippings.

Holding Cooked Vegetables

Cooked frozen vegetables lose ascorbic acid fairly rapidly. When cooked frozen green beans were held covered in a double boiler for 1 hr over a low flame with the water in the lower compartment boiling gently, only 15 percent of the original ascorbic acid was retained. Little loss of thiamin or riboflavin occurred.[54] When frozen broccoli which had been cooked in household amounts was stored in the refrigerator (40 F) for 24 hr, 19 percent of the ascorbic acid was lost; and at the end of 48 hr, 34 percent.[2]

Frozen broccoli which had been cooked in quantity amounts and then held for serving in a heated insulated service for 15 min, lost no ascorbic acid; for 30 min a small amount; and at the end of 2 hr one-third. No appreciable loss of thiamine or riboflavin occurred even at the end of 2 hr.[34] The drained, cooked broccoli held in cold water either at room temperature or in the refrigerator for 6 hr, and then reheated, either by heating in the water in which it had stood or by draining and adding it to boiling water, lost large amounts of its ascorbic acid, thiamine, and riboflavin as would be expected. Frozen peas, green beans, and lima beans held in their own

Table 8. The Effect of Long Cooking[1] of Commercially Quick Frozen Broccoli on the Retention of Ascorbic Acid, Thiamine, and Riboflavin[2]

Time of cooking, min	Retention, percent		
	Ascorbic acid	Thiamine	Riboflavin
8	61	56	56
24	46	44	48

[1] The broccoli was cooked in a 5-gallon steam-jacketed kettle with 8 quarts of water.
[2] Jones, Wood, Fenton, Harris.

cooking waters in the steam-jacketed kettle, lost ascorbic acid to the cooking water fairly rapidly; thiamine and riboflavin less rapidly.[5]

It is possible to serve cooked frozen vegetables which are approximately as high in nutritive value as are cooked garden fresh vegetables, and usually higher than cooked ordinary market fresh, canned, and cooked dehydrated vegetables. Understanding of losses which may occur, and constant vigilance, however, are necessary for this accomplishment.

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If you searched this chapter for something which was not found in it, please let the editors know.

10. STORAGE OF FROZEN FOODS

THERE is a unanimity of opinion relative to the serious effects of poor storage conditions on the quality and life of frozen foods. Although lean beef keeps about as well as any product in cold storage, it is not free from storage hazards. The degree of troubles that may occur to meat in cold storage is indicated in Chapter 24. Yet these may not be nearly so serious as what may happen to some poultry, fish, fruit and vegetable products. The quality of cold storage is just as important as the quality of the original product, or of the freezing process itself.

Tressler[1] has stated that the effect of various methods of handling on vitamins is a fairly accurate measure of the effect on quality of frozen foods as a whole. Thus even though vegetables are blanched, sufficient enzyme activity may remain to cause a steady loss of quality during prolonged cold storage.[2] Although variations in blanching, freezing and packaging may be responsible for loss of quality in cold storage, this chapter is concerned only with the effects of various storage conditions.

Effect of Temperature

Jenkins, Tressler and Fitzgerald[3] measured the loss of vitamin C during the storage of spinach, peas, broccoli, cut sweet corn, green snap beans and lima beans at temperatures of approximately 16, 10, 0 and −40 F. If the loss of vitamin C is representative of the **loss of quality** such as appearance, flavor and general nutritional value (as many investigators appear to hold true), then it would be foolhardy to store these vegetables at temperatures higher than 0 F. It has been found that even the low temperature of 0 F is not low enough to retain top quality in spinach and green snap beans. In most instances the quality depreciated as much as 50 percent in 2 or 3 months at a temperature of +16 F. (See Figs. 1 to 5, Chap. 9.)

Low temperatures prevent loss of moisture from products. At higher temperatures, the vapor pressure of the ice in the products is higher, and, since the wrapping materials are the same, the product stored at the higher temperature will dry out faster.

The vapor pressures, however, only tell part of the story. The **fluctuation** in storage temperature is the chief cause of the trouble. There is only one way to minimize the deleterious effect of wide fluctuations in temperature—to maintain lower storage temperatures than might otherwise be indicated.

Although the operator does not always have an opportunity to witness the damage to frozen foods caused by fluctuations of temperature, it is the consensus that at +10 F and above, a good quick frozen product will change into a typically slow frozen product in six months or less. It has also been noted that a room with small temperature fluctuations, say of plus or minus one or two degrees, will retain quality even at +10 F much longer than when fluctuations are of the order of plus or minus five or six degrees, as may often be the case. Fluctuations that cause serious damage at +10 F will do much less harm at 0 F or lower.

Humidity

The relative humidity of a cold storage room should tend to be higher, the lower the temperature. The room air contains less moisture per cubic foot, and the traffic in and out, plus moisture from products stored, tends to keep the relative humidity

JAMES P. POWERS, Author Chapter 10. Born 1897 in Gloucester, Mass. Formerly Rate and Billing Clerk, Railway Express Agency, 1919–21; Traffic Manager, White and Son, 1921–23; Railway Express Agency, 1923–26; Warehouse and Traffic Manager, General Seafoods Corp., 1926–30; Warehouse and Traffic Manager, New England Birdseye Operations, 1930–38; National Distribution Manager, Birdseye Frosted Foods, 1938–42; Warehouse Manager, General Seafoods Corp., 1942.

At present he is Manager Warehouses, General Seafoods Corp., Gloucester, Mass.

higher. However, this seldom exceeds 85 percent even in the best commercial freezers. There are several methods of maintaining higher humidities, but they usually are not practical for commercial operation. The Cook[3] method would put steam into the room as fast as it condensed or froze out. The installation of extra pipe surface areas is the most satisfactory, but it is expensive in pipe and storage space. However, a storage having at least 8 in. of insulation and about one linear foot of 2 in. piping for 3 cu ft of refrigerated space may be expensive to install, but the low temperature differential between the air and the coils will maintain maximum humidity and less desiccation of the product.

On the other hand, if possible savings in packaging materials allow the user to pay a higher cold storage tariff, then 90 to 95 percent humidities could be a commercial reality. In the meantime, the industry is relying largely on high quality packaging materials to prevent desiccation in storage.

Cold Storage Practice

When one talks about the storage of frozen foods, one usually refers to the cream of the frozen foods trade, which arrives in the warehouse in neat rectangular cartons of 50 lb or less. However, the warehouse also must be prepared to handle a heterogeneous mass of packages such as barreled and boxed poultry of numerous grades and qualities; cartoned and firkined butter; barreled strawberries and other fruits in sugar, and similar products in 30-lb tins; frozen whole eggs, whites and yolks in salt, sugar or glycerine; boxes of fish of assorted varieties and sizes, some of which must be opened and glazed every few weeks, or unboxed blocks of fish, which must be glazed even more frequently. These are the more usual commercial products, but cold storages may receive rabbits, venison, pheasant, partridge and other game and beef, pork, lamb and poultry from local individuals or butchers.

With such a myriad of special cases it is wise of the frozen foods distributor not to rely too much on the warehouse man. It is too much to expect him to be entirely familiar with the best methods of handling, storing and loading trucks and refrigerator cars for shipment. The frozen foods operator should provide the warehouse man with a few simple musts and it is important to have a mutual understanding of conditions prior to the actual storing of the goods to prevent a later misunderstanding relative to quality of product and storage and handling charges. Accordingly, a summary of practices is presented to provide a basis for the prospective frozen foods operator in dealing with cold storage warehouses.

Warehousing Responsibilities

The progress that has been made during the last several years in the frozen food industry has made the cold storage warehouse more essential than ever before, and careful warehousing supervision is absolutely necessary in order to maintain the

Table 1. Characteristics of Sodium Chloride Brine in Railroad Cars

Salt content, % by weight	Saturation, percent or degree salinometer reading at 68.0 F†	Minimum temp possible with sodium chloride brine, F	Approx. minimum temp in car with 7-in. insulation at 80 F outside temp, F
15	56.4	+12	+24
16	60.2	+10	+22
17	64.0	+ 8	+20
18	67.7	+ 6	+18
19	71.4	+ 4	+17
20	75.2	+ 1.5	+15.5
21	79.0	− 1.0	+15
22	82.7	− 3.8	+12
22.4	84.2	− 6.2	+10*
23	86.2	− 6.3	—
23.1	86.8	− 8.3	—
23.5	88.4	− 0.5	+14.5
24	90.3	+ 5.0	+17.5
25	94.1	+15.0	+26

* The above table has been compiled from numerous sources, including the author's personal notes. Existing confusion appears due to lack of differentiation between brines and salt-ice mixtures. Example: a 22.4 percent brine is eutectic for hydrated salt ($NaCl \cdot 2H_2O$) and gives an 84.2° salinometer reading; a 23.1 percent brine is eutectic for anhydrous ($NaCl$) salt and gives an 86.8° reading. On the other hand, a mixture of 100 parts ice and 33 of salt (24.8 percent by weight) gives on melting a brine of 93.2° salinometer, and a minimum temperature of −6.3 F, the lowest recorded temperature for an ordinary ice-salt mixture. In practice a mixture of 100 lb of ice and 30 lb of salt is referred to as a 30 percent mixture when it is really only 23.1 percent by weight. Such a mixture will produce a temperature between −2 and −6 F. Thus it appears necessary to add 7 or 8 percent additional salt to obtain a minimum ice-salt mixture temperature comparable with that obtainable for any given strength of brine.

† 26.6 percent brine is saturated at 68 F.

gh standard already established by the dustry in other particulars. There has een so much experimentation and so uch care taken in handling the product efore freezing, that it is only logical that ne warehouses would take every precauon to keep the product at its best afterard. Zero to −10 F is accepted as best

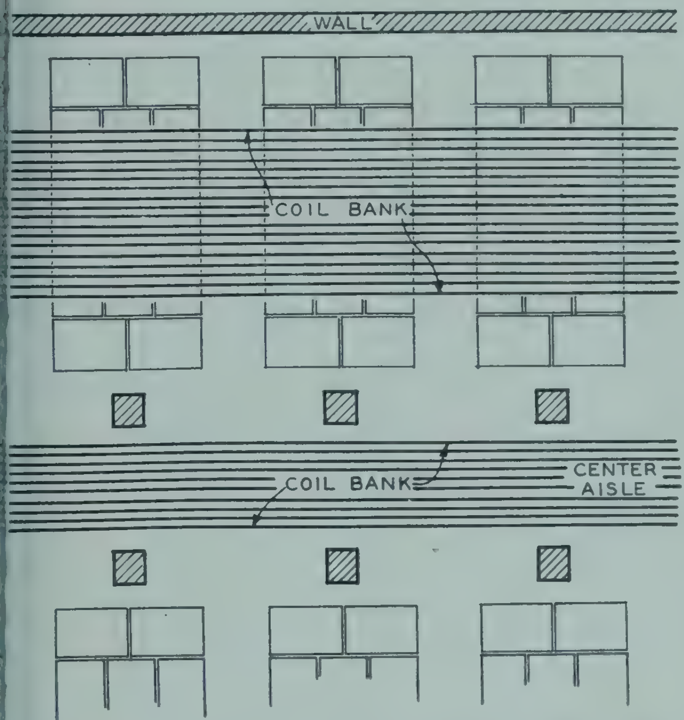


Fig. 1. Plan of Part of Cold Storage Room. A Typical Layout or Storing Frozen Foods, Locating Wall and Column Racks nd Floor Dunnage to Separate Products from Contact with Sources of Refrigeration Losses.

for frozen foods. The lower the temperature, the less enzymatic action and the fewer changes in color, flavor, texture and vitamin content and the longer the product can be held in storage.

Public warehouses are so well equipped that they are able to handle many different products at various degrees of temperature. Some products are received frozen and are to be stored immediately; other products such as fruits in 50-gal barrels and 30-lb tins may have to be frozen before being stored.

Receiving refrigerator cars and trucks. Upon receipt of a car of frozen merchandise, notification is sent by the railroad, to the consignee, who then presents the bill of lading and proceeds to unload the car. There is an obvious advantage when a warehouse is so situated that the car is delivered directly. Before unloading, the ice bunkers should be checked noting the amount of ice in the bunkers and a salinometer reading is taken as a measure of quality of the ice-salt mixture. This reading of the brine is taken outside the car from the brine-dip from the ice bunkers. At 68 F the salinity should register at least 86.8 percent **(Table 1).**

The seals are then broken on the doors. Temperature readings should then be made of air and products, if possible, at each end and in the middle of the car. The air temperature is taken by hanging a thermometer in the car. At the same time another thermometer is thrust between packages inside one of the cases of goods, which has been opened for this purpose and is then closed again. The car door is then closed for 15 to 20 min, after which readings are taken on the thermometers. If only one thermometer is available the product temperature is taken in the manner described above except that the cases used are first removed to a cool room in the warehouse. Unloading the car should be as fast as possible, and the product should be stored immediately in the holding room.

Stacking loads in warehouse. The storage room floor should have open racks from 2 to 3 in. from the floor and free from any obstruction so as to allow a free flow of air under and throughout the products. These should be placed in "open" stacks to allow rapid reduction to room temperature, as during shipment the temperature usually has risen to 10 or 15 F. For long-term storage, closed stacks prevent evaporation and restacking is of great advantage in this respect and worth the extra expense.

Products which are packed in cartons or cases should be piled in blocks having alternate tiers of 5, 7 or 9 containers with sticks or dunnage, about ⅜ in. thick, be-

tween tiers, or at least every second and third tier in order to allow proper air flow and adequate refrigeration **(Fig. 3).** Wood laths form suitable dunnage. This method of piling provides maximum stability and air circulation. Alternate tiers of 5's are more popular than 7's or 9's.

The products should be kept at least 6 in. from walls of inside rooms and their overhead refrigerating coils; and 12 in. from outside walls and 18 in. from coils of outside rooms.

It is necessary to keep the refrigeration coils free from surplus snow by scraping and bushing the pipes at frequent intervals, in order to obtain the lowest temperature and to eliminate cost of added refrigeration.

Storage rooms where frozen vegetables are held should be at −10 F, and, because of the sugar syrup in some fruits such as strawberries and raspberries, −15 F is considered best. These products should also be placed in a center storage room, which should be the coldest room in the warehouse.

Daily records of temperature should be taken of the various holding rooms in order to eliminate all possible causes of fluctuation in temperature. The rooms should, of course, be kept at the same temperature at all times.

Receipt of trucks. The contents of the load must be carefully counted in order to check with the bill of lading.

The warehouseman should know the approximate distance from points of origin to destination in order to determine the length of time the products have been en route, and a record should be made for future reference regarding the condition of each shipment received. The truck should be checked as to floor and side racks, condition of body, and the amount of dry ice left unused. The product should be carefully examined as to its condition and temperature.

Should the product show any signs of defrosting, as soon as possible it *must* be stored temporarily in "open" stacks in a low temperature holding room and moved later to its permanent place **(Fig. 2).**

Inventories. Upon receipt of each new shipment in a warehouse or holding room a stamp indicating lot number and date received is put on each piece for future

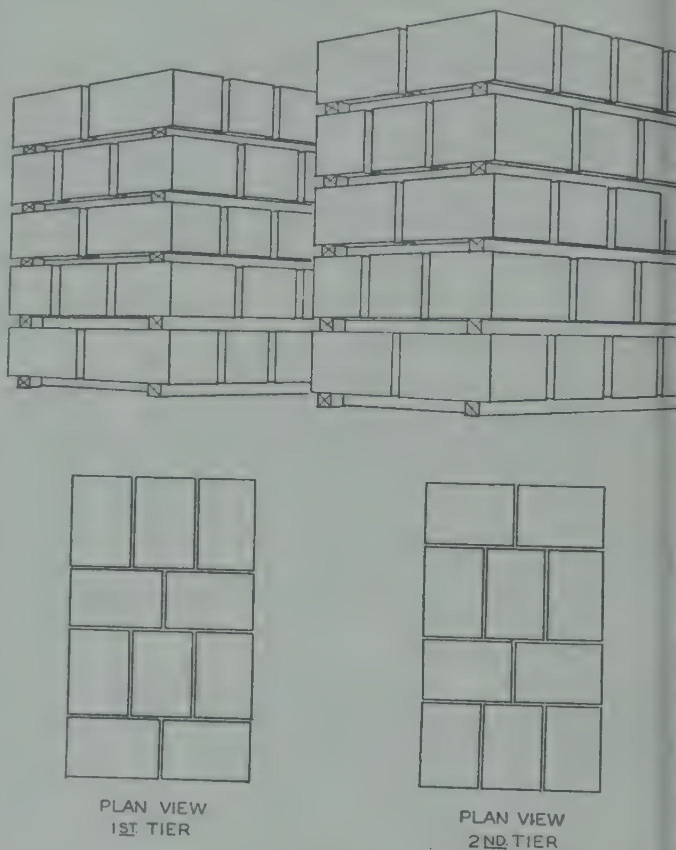


Fig. 2. Stacks of Alternate Tiers of 5's, Showing Wall Racks, Floor Racks, and Dunnage Between Tiers. Note Formation of Units of 5's by Placing the Ends of 3 Cases Against the Sides of Two Cases.

reference, and all lot numbers are kept separate. A card record or inventory is kept of each lot showing the number, date received, number of pieces and kind of product in the lot, also the holding room in which the lot is stored. This is, of course, for convenience in ordering out.

All withdrawals from each lot are posted on the cards daily showing the date of withdrawals and the number of pieces withdrawn. The oldest lot numbers are

used first. As new lots are constantly being entered it is always necessary to leave aisles for removal of the older lots in the most convenient manner.

A delivery record book is kept covering small shipments and showing the date of delivery, to whom delivered, number of pieces delivered, lot number, kind of product and the signature of the truck driver or receiver. (Carloads and truckloads are covered by the bills of lading.)

Storage billings are sent to customers each month according to the inventory records, together with notification of expiration date on any lot nearing the expiration date set by the state law.

Most states allow storage of frozen products from 10 to 12 months, and they are expected to be withdrawn from storage by the expiration date. However, an extension of time is usually granted by the state upon request of owner provided that the merchandise has been approved by a state inspector upon examination. This extention is usually from one to three months by which time the product should be withdrawn.

Freezing in Warehouses

Still air. Freezing of meat, fish and game was probably done naturally in frigid climates hundreds of years ago in order to guarantee having the food during the winter. Little progress had been made along this line until about the early nineteen hundreds when experiments were made, with some success, to preserve fruits by means of mechanical refrigeration. These practices have been improved and standardized, and they are still being used.

This method, called still-air freezing, is used for fruits for the commercial trade. The fruit is mixed with sugar and packed in 30-lb tins or 50-gal paraffin-lined barrels, weighing about 450 lb. The fruit when ready for freezing is put directly into a low temperature storage and left until completely frozen. At intervals during the freezing process the barrels are rolled, in order to facilitate freezing and to make a more even mixture of juice and fruit. The completely frozen product is then stored at +15 F.

Blueberries and other items to be frozen loose in wooden boxes have dunnage or space sticks between each tier for better circulation. When the products are frozen, the boxes are stacked solid on top of each other.

Table 2. Storage Temperatures—Relative Humidities—Storage Life*

Commodity	Temperature °F	Relative Humidity (percent)	Storage Life (months)
Bread	0–10	80 or above	10–12
Butter	0 or below	80	8–12
Cottage Cheese	0 or below	—	2–6
Cigars	0 or below	85	3–5
Frozen Cream	0 or below	—	8–12
Eggs			
Dried	30–32	65–75	6–10
Liquid	0 to −5	—	6–10
	−10 or below	—	12–24
Fish			
Demersal	0 or below	80 or above	12
Pellagic	−10 or below	80 or above	6–10
Frog Legs	0 or below	80 or above	4
Fruits			
Cold Pack	0 or below	—	10
Quick Frozen	0 or below	80 or above (Dry Pack)	10–12
Juices	0 or below	—	6–12
Furs			
Raw	0 or below	—	6–8
Garments	33 or below	80 or above	6–8
Skin and Pelts	0 or below	—	3–5
Ice Cream	0 or below	60	2–4
Meat			
Beef	0 or below	80 or above	10–12
Pork, etc.	0 or below	80 or above	6–10
Game	0 or below	—	3–4
Cured	12 or below	—	1–4
Pickled	12 or below	65–70	3–6
Poultry			
Broilers and Fryers	0 or below	80 or above	12
Roasters	0 or below	80 or above	10–12
Fowl	0 or below	80 or above	8–10
Turkeys	−10 or below	80 or above	6–8
Game	−10 or below	80 or above	3–4
Shellfish			
Shrimp	0 or below	80 or above	6–8
Wheat Germ	0 to 32	80	2–3

* Adapted from U.S.D.A. Cir. #278 (1941).

Glazed fish, such as panned mackerel and whiting, are prepared by putting the whole cleaned fish in pans and leaving them in the low temperature room until frozen into a block; then they are removed from the pans, dipped in cold water to glaze them, and stored. The fish should be reglazed at least every two months by immersing them in water while still in the storage room. The reglazing is necessary to prevent their drying out once the original glaze has evaporated.

Quick freezing. Quick freezing is done by various methods at low temperature in a minimum of time. Some of the rep-

resentative methods are:

Birdseye multiple-plate froster—double metal contact

Murphy—combination contact, metal and air

Finnegan—tunnel, controlled air contact

Z system—brine spray or fog.

There are other methods also used, such as liquid immersion, forced air circulation and sharp freeze rooms.

The following describes one widely used commercial method. Plate frosters consist of a series of flat plates one above the other through which there is a constant flow of refrigerant (ammonia) which freezes the product at a temperature of −25 F. These frosters can freeze packages up to about 5 in. in height. The plates are raised by hydraylic rams for contact with product during freezing and later lowered for unloading. One froster is capable of freezing up to 4000 lb of product at one operation; this of course depends on the type of product and size of carton. (See Chaps. 1, 2, 3.)

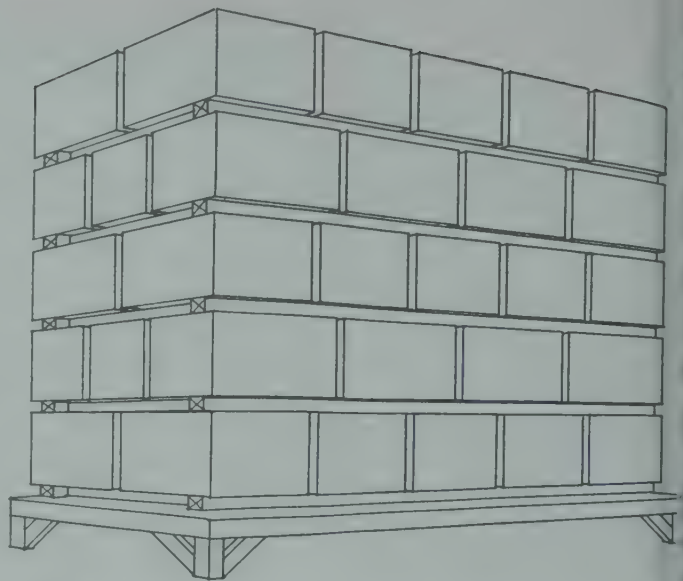


Fig. 3. Method of Open-Stacking to Allow Rapid Remova[l] of Heat Picked Up in Transit. Such Loads are Convenientl[y] Placed on Skid Platforms to Facilitate Removal from Temporary Holding Room to Permanent Storage.

placed on top of the product. Four or more 50-lb blocks of dry ice may be spaced on top of the load to insure an even temperature throughout. To calculate the amount of dry ice necessary, the following formula may be helpful:

$$\text{pounds of dry ice} = \frac{\text{(sq ft inside truck area)} \times \text{(hr in transit)} \times \text{(degrees difference between desired inside and expected outside temperature)}}{\text{(inches of truck body insulation)} \times (269)}.$$

As a short cut, determine the area of one side and multiply by 5, because the front and back about equal one side.

Truck Shipments

All large transportation companies are equipped with modern refrigerator trucks for capacity or less than truckloads for long or short hauls. Dry ice, eutectic ice, hold-over tanks, or mechanical units provide the refrigeration.

Trucks should be inspected as to general condition, care being taken that floor racks and both side and end wall racks are in place. When shipment is known in advance the truck should be precooled. The same steps should be taken in loading a truck as in loading a car except that dry ice is placed on top of the product.

Reicing of the truck is done en route when necessary, as directed in the bill of lading.

The bill of lading is made out in triplicate in the same manner as for a carload, except that it is signed by the truck driver who then assumes the responsibility for his company, for the delivery of the load.

Some warehouses have inaugurated a system to pack or repack frozen foods into small lot shipments for customers. These are usually shipped by trucks or via Railway Express, and dry ice is used to protect the product from defrosting in transit.

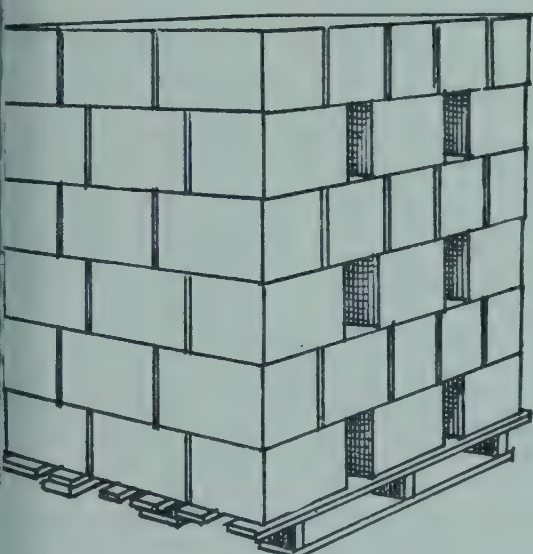
Jsually oversized containers are used to llow room for the desired amount of dry e. The latter is usually wrapped in heavy ianila paper to reduce the evaporation ate.

Carload Shipments

(See also Chapters 20, 21, 32)

Refrigerator cars should be ordered in dvance of shipment from the local railbad company and should then be **pre-ooled** for 24 hr before loading.

Cars should be inspected and swept out or good circulation, and side racks and oor racks should be in order. Precooling s done by filling the bunkers, at the ends f the refrigerator car, with lump or rushed ice mixed with coarse salt.



ig. 4. Palletizing Reduced Handling Costs from Plant to Market.

Twenty to twenty-five percent salt by veight (or 25 to 33 lb of salt per 100 lb of e) is usually used depending on outside emperature and destination of car, the igher ratio giving in a well-insulated car minimum brine temperature of about -6 F and an average car temperature of +12 to +15 F (Table 1). Ice bunkers old about 12,000 to 14,000 lb of ice.

Products should be taken directly from he cold storage room, checked into car, nd loaded as quickly as possible, being so tacked that the load will not shift its position in transit. The car may be loaded solid from end to end, or occasionally a client may prefer or require a small aisle to be left open in front of the doors for circulation. In this case dunnage is used for constructing braces to keep products from shifting. Newer cars may have forced-air circulation which now use more ice and salt but allow lower temperatures and a solidly stacked load.

Products, although stacked solidly from end to end, should be stacked only to within 16 to 18 in. of the top of the car for good circulation. Fibre paper is then placed on top of the products and where possible down over the sides and ends of the load. This confines the coldest air next to the products themselves so that, although the whole load may rise somewhat in temperature, defrosting at exposed surfaces is less likely to occur.

Some companies prefer to use heavy paper to enclose the product completely, forming a sort of bag on bottom, sides and top. In this way they attempt to keep the temperature nearly uniform in the whole load, or at least to keep the outside cartons from defrosting first.

When the loading of the car is completed the bunkers are "topped off" or refilled with ice and salt. The doors are then sealed and the car is ready to be picked up by the railroad company for delivery at its destination.

A bill of lading must be made out in triplicate form covering car shipments denoting consignee, destination, car numbers, seal numbers, number of pieces and kinds of product, reicing instructions and also noting whether car is being forwarded with charges collect or prepaid. The bill of lading is signed by the warehouseman or shipper denoting delivery of car to the railroad and it is also signed by the railroad acknowledging receipt of car. The original copy of the bill of lading is sent to the consignee, the second or shipping copy is retained by the railroad, and the third or memorandum copy is kept by the warehouse office for its files.

Reicing instructions vary at the shipper's discretion depending on the seasonal outside temperature and the destination point. The reicing is done by the railroad

at any or all of the icing stations en route as per bill of lading.

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If you searched this chapter for something which was not found in it, please let the editors know.

11. PACKAGING OF FROZEN FOODS

THERE is much evidence in the literature to indicate that wrapping and packing materials have an important influence on the retention of quality of frozen foods.[3,4,7,8,9,12,13,14,15,16,23,25] However, the basic reasons for the protective value of the more effective materials are not so well understood.

Permeability.—Throckmorton[21] believed that the most universal problem in packaging foods is to prevent the transfer of gases and vapors through the walls of the container. Since that time (1942) the permeability of many sheet materials to gases and moisture-vapor has been determined at above-freezing temperatures and various relative humidities, but no comparable data are available under low temperature storage conditions.

A major problem in the storage of frozen meats is to retard the development of rancidity of the fats. Efforts to stabilize fats usually are concerned with the prevention of changes caused by enzyme action and by atmospheric oxidation.[11] The term "oxidative rancidity" is used to denote the deterioration in flavor and odor that occurs when atmospheric oxygen reacts with the triglycerides or other components of natural fats.

Excessive weight losses (5 percent or more) resulting from the use of packaging materials having relatively high rates of moisture-vapor transmission have been cited as a major cause of quality deterioration. Nevertheless, it is readily demonstrated that excessive loss of weight, *per se*, is not necessarily correlated with loss of palatability. It was found that the packing of adequately processed green beans in stockinette only,[24] and the packing of ground beef in hermetically sealed containers with an inert desiccant[18] resulted in little loss of flavor during periods of storage in which the weight losses exceeded 5 per cent.

Effect of oxygen.—In one experiment,[18] metal containers were filled to about one-third capacity with ground beef and stored at 0 F. Atmospheres of low, medium, and high oxygen content under both normal and low relative humidites were maintained in the containers during storage periods up to 7 months. There was a significant decrease in palatability with an increasing oxygen content of the atmosphere

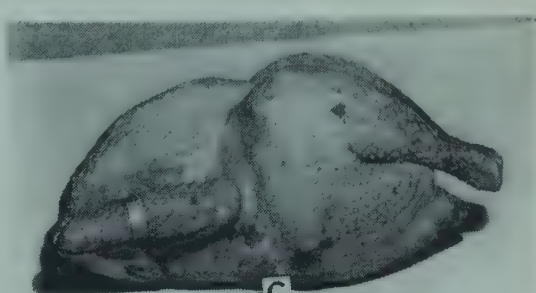

Fig. 1. Chicken stored for 11 months at 0 F in a single wrap of aluminum foil, gauge .0015″. Appearance was bright and there was no freezer burn. Weight loss was 0.29 percent. Natural flavor and juiciness was well retained.

JAMES D. WINTER, Author Chapter 11. Born 3/25/92 in England. Educated at University of Minnesota, BS, 1923; MS, 1929. Formerly with Plant Quarantine and Inspection, Minn. Dept. of Agri., 1929–33; Sec'y.-Treas., Minn. Fruit Growers Assn. since 1933; University of Minnesota, Instructor in Horticulture, 1937–42; Asst. Prof. 1942–47; Assoc. Prof. since 1947; Orchard and Garden Editor, *The Farmer* (St. Paul) since 1939; Editor, *Minnesota Fruit Grower*, 1933–47.

Co-author "Freezing Foods for Home Use," 1949; Univ. of Minn. Ext. Bul. 244 and several other Univ. of Minn. bulletins on frozen foods and on growing, handling and transportation of fruits; Author of "How to Use Your Home Freezer," 1948, McGill-Warner Co., St. Paul, Minn.; articles in *Refrig. Eng., Locker Management, Locker Operator, Ice and Refrigeration*, and *Food Freezing*.

Member of Inst. of Food Technologists; Amer. Soc. Hort. Sci.; President, Minn. State Hort. Soc., 1929; Member, Sigma Xi; Gamma Sigma Delta; Guest Member, Amer. Soc. of Refrig. Engrs., 1949–50.

Awarded Bronze Medal, Minn. State Horticultural Society, 1945. At present, Associate Professor, in charge of Frozen Food Research Laboratory, University of Minnesota.

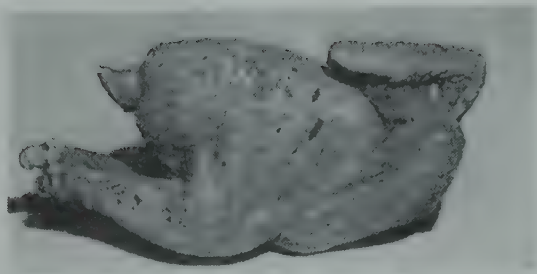

Fig. 2. Chicken stored for 11 months at 0 F in a double wrap of waxed locker paper. Note severe freezer burn. Weight loss was 1.45 percent. When cooked, the fat had a rancid flavor.

surrounding the meat. The data indicated little difference in flavor between lots having low weight losses and those having high weight losses resulting from excessive desiccation.

On the other hand, weight losses in foods sold by the pound are very important from the commercial viewpoint. Furthermore, excessive weight losses frequently are accompanied by a deterioration in appearance of the product such as the so called "freezer-burn" of meat.

It seems apparent that wrapping and packaging materials for frozen foods should have low rates of transmission for both oxygen and moisture-vapor at tem peratures of 0 F or lower. These valu are not critical for short storage perio because loss of quality resulting from po packaging seldom is apparent during th first few weeks of storage.

The use of antioxidants impregnate into cardboard and dispersed in the coa ings of cardboard and paper has been su gested as a method of retarding rancidit development in packaged fat-containi foods,[6] and at least one wrapping materi of this type has appeared on the marke An aqueous solution of ascorbic acid al has been used for fish fillets as a dip prior t packaging.

Moldability.—Sheet or bag materials good protective value should be pliab enough to make a close, tight wrap, b cause the amount of air space inside package in relation to the volume of foo and the surface area exposed should b held to a minimum. A completely moi ture-vaporproof seal cannot protect foo from loss of moisture if large cavities exi within the package. In such a situati moisture from the food is deposited as i crystals inside the package.[17,22] Temper ture fluctuation is the principal cause

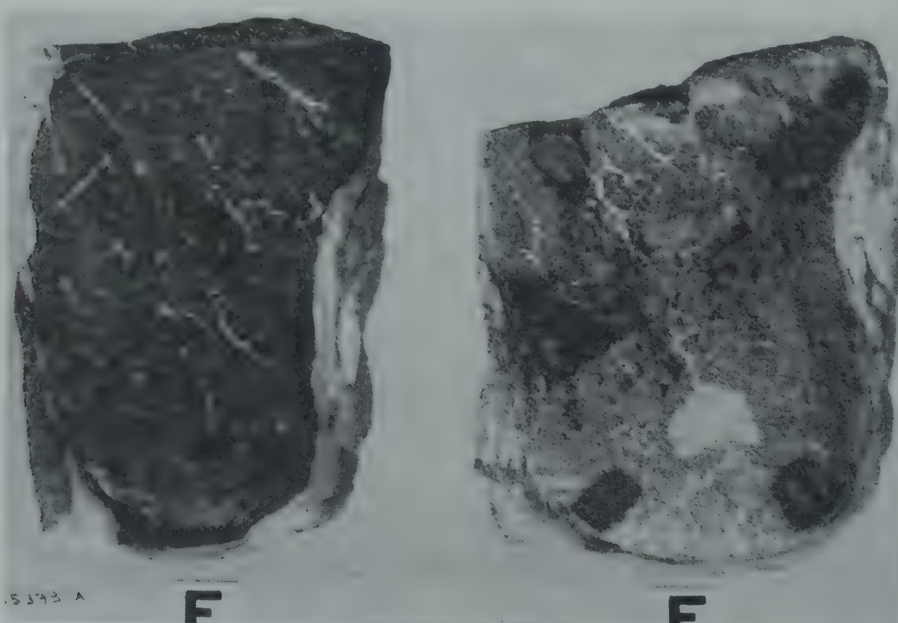

Fig. 3. Condition of steaks after 7½ months' storage in fluctuating temperatures. About 30 fluctuatio in range of 0 to −20 F occurred during this period.

Left—steak wrapped in laminated aluminum foil, condition excellent, no freezer burn. Weight loss 0 percent. Right—steak wrapped in waxed locker paper, severe freezer burn. Weight loss 15.6 percent.

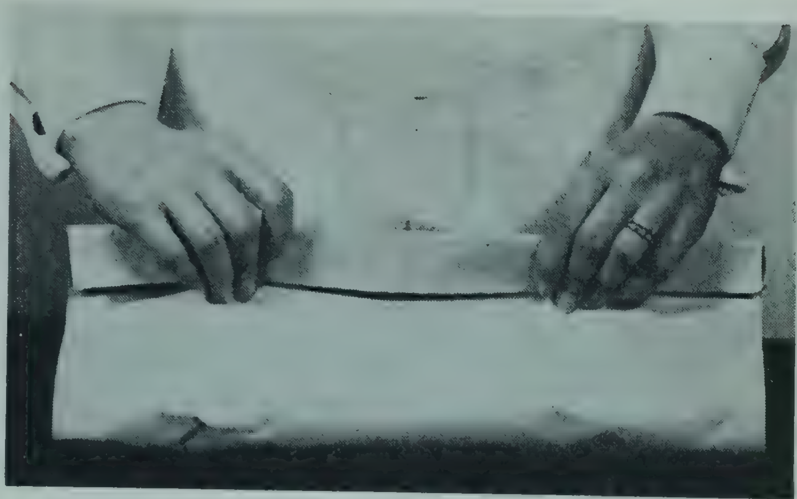

Fig. 4. Start a druggist-type wrap by folding edges over, usually twice, to make a tight lock seam. A tight, snug lock seam should be made, except when using foil. Use locker tape or twine to hold the end folds in place. Tape is preferred because it holds down the ends very securely.

transfer of moisture from the food to the surrounding air space.

Ice crystals do not build up inside a package when the packaging material has a relatively high rate of moisture-vapor transmission.[22] Under such conditions, and when the permeability to oxygen is high, it is probable that air pockets inside the package are of little added significance.

The Tappi* method of testing moldability consists of placing a one-pound weight for 30 seconds on sheet material folded at a 360° angle. The "spring-back" when the weight is removed is measured in degrees with a protractor.

Greaseproofness.—When fats are absorbed by a packaging material a large surface area is exposed to atmospheric oxygen and the development of rancidity is greatly accelerated throughout the product as well as on the surface.[6] Therefore, the use of a greaseproof material is desirable. The greaseproof qualities of certain sheet materials are given by Lavers;[10] cellophane, Pliofilm and vinyl derivatives are listed in first place followed by polyethylene, glassine, vegetable parchment, "greaseproof" papers, and waxed papers in the order named. It was noted that uncreased glassine was 5 to 10 times better than parchment, but creasing greatly decreased the grease resistance of glassine. Aluminum foil, which has excellent greaseproof qualities, was not included in this test.

Other desirable qualities.—A wrapping material for frozen foods should have other

* Technical Association of the Pulp and Paper Industry.

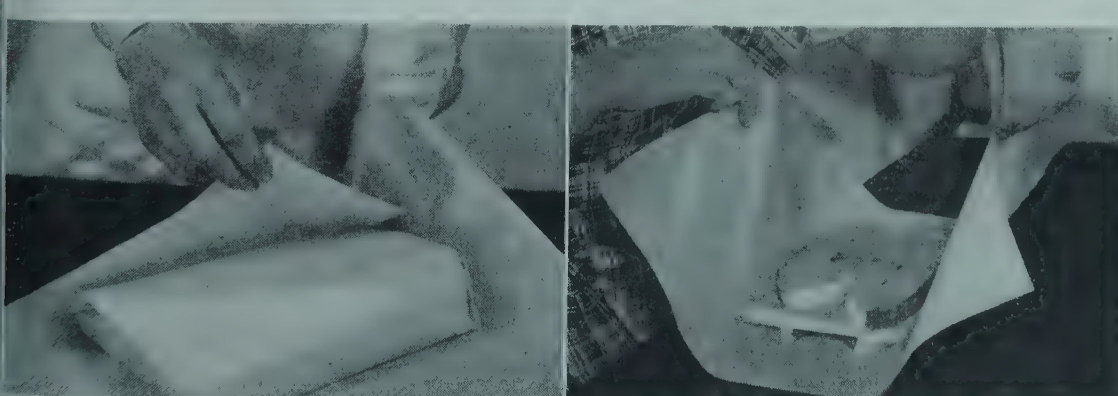

Fig. 5. Left—The butcher-type wrap is started by placing the meat close to one corner of the paper. A double wrap should be used with waxed locker paper.
Right—Use locker paper between layers of fish, chops, steak, or cut poultry, so that the pieces may be separated easily after the product is frozen. Note that the product is placed in the center of the wrapping when starting a druggist's wrap.

Fig. 6. Left—Foil may be used for wrapping poultry and other unevenly shaped products. In making the lock seam, do not draw the foil too tight; allow surplus to press and mold tight around the product. Press while the ends are still open.
Right—Close a foil wrap by pressing the ends of the wrap, starting next to the product. Then fold over to make a lock seam and press snugly against the product. No tape or twine is needed.

qualities in addition to those previously described. The material should be odorless, especially when damp; should possess high wet strength so that meat juices or other liquids will not cause it to soften and break. It must also be strong enough to resist tearing and puncturing in wrapping and handling; be easy to mark for identification and date of packing; and not become brittle or crack at low temperatures. A sheet material should have good "stripping" quality so that it will not adhere to the meat when the package is unwrapped. A Mullen test of not less than 32 pounds is considered the minimum bursting strength desirable for waxed paper and laminated sheets. This test measures the pressure necessary to rupture a circle of sheet material having an area of one square inch. For locker plant use, a sheet material should be usable on a paper cutter.

Sanitary standards.—Investigations[20] have shown that, in general, paper and paperboard products made for food packaging meet high standards of sanitary quality in manufacturing processes. The undesirable practice of retailing frozen food containers from bulk stock has largely been discontinued in favor of factory packaged units for retail distribution.

Storage of wrapping materials.—Careful attention should be given to the recommendations of manufacturers concerning the proper storage conditions for the various packaging materials. For example, waxed papers may stick as a result of high temperature storage. They should be stored in a cool place, if possible not over 70 F. The optimum storage condition for cellophane is 65–75 F at 50–65 percent relative humidity for bags, or 35–50 percent for rolls. Pliofilm stores satisfactorily under normal room conditions. Aluminum foil should be kept in a dry place and care must be taken to avoid damage to the ends of rolls by dropping or careless handling. Some difficulties may be encountered in the use of materials that have been stored improperly.

Types of Packaging Materials

Wrapping and packaging materials for frozen foods may be divided into three general groups, namely, (1) sheet materials, (2) dip coatings, and (3) containers. Containers include bag types formed from sheet materials; in many instances containers are overwrapped with one of the sheet materials.

Sheet Materials

Sheet materials are available in four distinct types; films, laminated sheets, foil and paper coated with wax on plastic. The coated papers, as a group, provide less effective protection to the food than the

other three types of sheet materials.

A survey[2] made among 10,715 locker plants during June, 1948, showed the following usage of wrapping materials. Many plants offer more than one type of wrap.

Type of Wrapping Used	*Number of Plants*	*Percent*
Waxed locker paper	7,008	65.4
Cellophane	2,250	21.0
Laminated glassine	2,111	19.7
Aluminum foil	1,714	16.0
Double wound cellophane	1,211	11.3
Laminated cellophane	568	5.3
Thermoplastic wax dip	557	5.2
Laminated aluminum foil	396	3.7
Pliofilm	396	3.7

Transparent films. *Cellophane.*—Cellophane is a non-plastic film of regenerated cellulose. Cellulose alone has little protective value for frozen foods unless coated. Of the many types of moisture-proof cellophane, very few are recommended for wrapping moist foods such as meat. Dupont cellophane MSAT 83 or 87, or Sylvania cellophane MSBF-3 should be used for moist foods. Unfortunately, the wrong types of cellophane are frequently sold for freezer wrappings. Although such types often are labelled "made for frozen foods" they may be intended for wrapping and freezing dry products rather than moist meat. The MST-53, MSF-1, and MSF-3 types of cellophane are suitable for wrapping dry or pre-frozen foods, but the protective coating is not water-repellent and is likely to loosen in contact with moist foods. Gauges commonly used in frozen food packaging are No. 300 (.0009″) and No. 450 (.0013″). No. 300 cellophane used as a meat wrap usually requires an outer wrap of stockinette or paper to protect it from breakage in locker plant handling. No. 450 cellophane often may be used without an overwrap. The proper types of cellophane are effective barriers to oxygen and moisture vapor. A special type of standard paper cutter is used for cellophane.

Cellophane also is available as a "double-wound" locker wrap, comprising a cel-

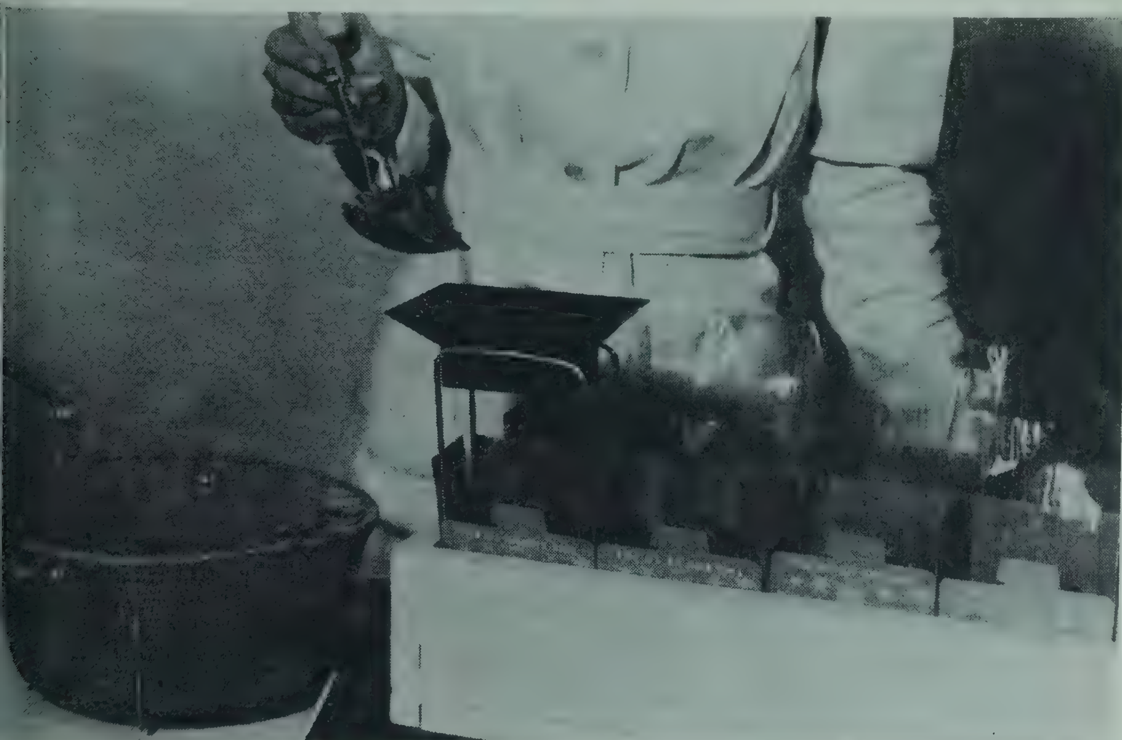

Fig. 7. The bag-in-box type of carton may be filled easily by using a simply-made wooden form to hold the cartons upright. Another aid in this operation is a carton filler consisting of a wire frame and a funnel.

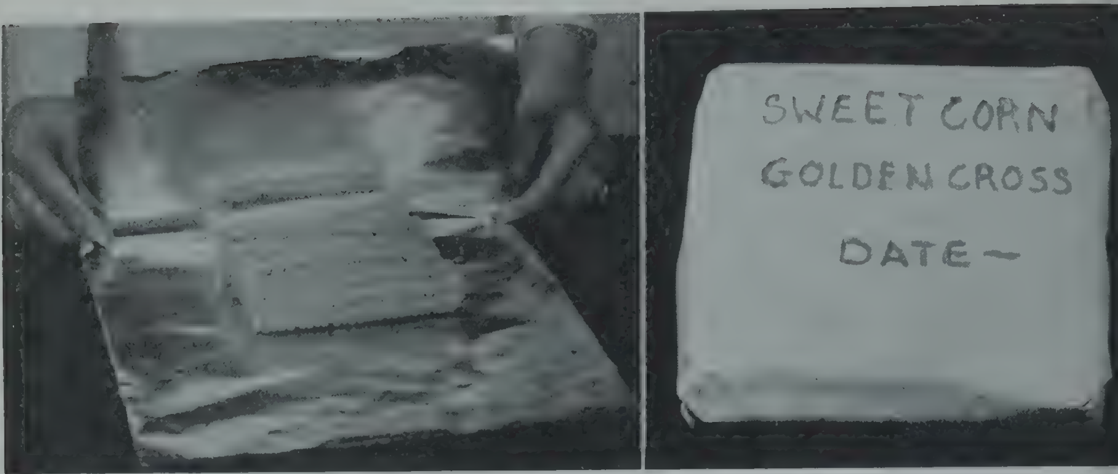

Fig. 8. Left—When wrapping with laminated foil, use the aluminum side next to the product. Right—Make a snug, tight wrap. Label and date the package.

lophane inner wrap and waxed locker paper wound together on the same roll.

Pliofilm.—Pliofilm is a transparent film of rubber hydrochloride. The FF type is recommended for frozen foods. Gauges No. 120 (.0012″) and No. 140 (.0014″) are commonly used, although for some applications a lighter gauge (Nos. 75 or 100) may be used. This film usually requires an outer wrap to protect it from breakage in locker plant handling. Pliofilm is an effective barrier to oxygen and moisture-vapor. These qualities are inherent in the film. It is very pliable and has high tensile strength. The tensilized (stretched) film will shrink when dipped momentarily in water at approximately 180 F. If desired, Pliofilm may be washed in hot water for reuse.

Saran.—Saran is a transparent film of polyvinylidene chloride. It has a high resistance to tear, but when a tear has started the resistance is lowered. Saran No. 517 is the recommended type. This film has a strong tendency to "cling," making it difficult to handle, but new types are being developed to avoid this problem. Saran is an effective barrier to oxygen and moisture-vapor.

Polyethylene.—A transparent film of polymerized ethylene. Ethylene, a gas obtained from petroleum, is polymerized at high pressures and elevated temperatures to form polythene from which the film is made. Polyethylene is the lightest and most inert of the plastic films suitable for frozen food packaging. It is durable and tough at both normal and low temperatures, and possesses a good degree of transparency. Polyethylene does not soften until heated to about 212 F so it may be washed in water as hot as the hands can stand. This film does not tear readily so it is unsuitable for use in sheet form on a standard paper cutter. It is available in sheet, tube, and in bag form.

Polyethylene is one of the newest plastics. It was developed in England and first introduced into the United States in 1943. It is sold under a variety of trade names such as Howard-Seal, Pearlon, Shellene, Tralon, and Visqueen. Polyethylene is an effective barrier to moisture-vapor but it is not equal to some of the other frozen food films as an oxygen barrier.

Aluminum foil. Aluminum foil is sheet aluminum less than .006″ in thickness. It is very moldable, permitting a snug wrap for irregular objects such as poultry and fish. Foil is a very good conductor of heat, so that foods freeze faster in foil than when wrapped in locker paper. It may be used with the shiny surface on the inside or outside of the package, but the dull side is preferred on the outside for ease of marking. Special inks are available that mark foil very satisfactorily either with stamp and pad or with brush pen.

Foil may be used on a standard paper cutter having teeth on the cutter bar. Plain foil lighter than .001″ is not desirable because of pinholing and poor stripping quality. The recommended thickness is .0015″

in widths of less than 24 inches, or .002″ in 24-inch widths. Aluminum foil of suitable gauge is an effective barrier to oxygen and moisture-vapor, and it retains its strength and flexibility at extremely low temperatures.

Meats and poultry may be oven-roasted after partial or complete thawing while still wrapped in foil, resulting in considerably less shrinkage than if the meat is cooked uncovered.

Aluminum occurs naturally in plant and animal tissues and its use as a wrapping material does not affect the wholesomeness of food in any way. Neither does it accelerate the loss of vitamins during cooking.

Fig. 9. Meat wrapped in cellophane or pliofilm should be covered with stockinette or other protective outer wrap.

Aluminum and nickel were the only metals tested by Ziels and Schmidt[26] that were found to be absolutely free of any pro-oxidant effect on fat. Bryan[5] reports that four generations of rats were fed on foods which were not only packed in aluminum but which also had relatively large amounts of the metal intermixed. Growth and fertility of the rats continued normal with the aluminum completely excreted.

Laminated and plastic coated sheets. Many types of laminated sheets are available for wrapping frozen foods, comprising two sheet materials laminated together by flexible adhesives. They include cellophane to paper, aluminum foil to paper, glassine to paper, glassine to aluminum foil, and others. Glassine is made by partial gelatinization of wood fibers in prolonged beating previous to the formation of the sheet of paper. In general, laminated sheets are effective barriers to oxygen and moisture-vapor. When paper is used as one of the sheet materials, the paper side is used on the outside of the package. One of the latest developments is a sheet made of polyethylene coated on paper. Tests of such sheets indicate they are good barriers to moisture-vapor, only moderate barriers to oxygen.

Waxed locker papers. Tests of foods stored at 0 F indicate that most, if not all, waxed locker papers now in general use have only a moderate protective value for frozen foods, except for relatively short storage periods. A single wrap of one of the more effective materials will give better protection than a double wrap of an ordinary waxed locker paper. Waxed locker papers of 40 to 48 pound weight are most often used, this being the weight of 480 or 500 sheets each 24 × 36 inches.

Dip coatings. A number of investigations of thermoplastic dip coatings have been conducted at the Western Regional Research Laboratory, U. S. Department of Agriculture, and elsewhere. Commercial equipment for dip coating has been developed and is in use at some locker plants. The procedure involves freezing the food unpackaged and then dipping it in the molten thermoplastic mixture at approximately 145 F. The coating quickly solidifies after removal from the dip and forms a continuous protective film. Some weight losses occur in freezing the unpackaged food but these losses appear to be of no consequence in quality retention. When forced air circulation is used in the sharp freeze compartment, it may be desirable to install an adequate air filter to protect the unwrapped food from contamination during the freezing process. In general, this method appears to provide effective protection for frozen foods. An investment of about $200.00 in equipment is necessary.

Another type of dip coating has been suggested for use on fish fillets consisting of an aqueous solution of refined Irish moss extractive to which an antioxidant is added.[19] After dipping and draining, the fillets are over-wrapped in cellophane or other protective sheet.

Wrapping methods. The method of wrapping and closing a package may be as important as the choice of the material used.

Many tests indicate that wrapping methods recommended for locker plant and home use are effective even though the closure does not have a completely airtight seal. It is unlikely that the significant differences usually found in experimental lots of meat wrapped in sheet materials of widely different protective value would occur if major losses take place through the folds of a well wrapped package fastened in the usual way with tape.

With sheet materials, the "druggist's wrap" is the easiest method of making tight folds and a close, tight wrap. This wrap also takes about 20 percent less wrapping material than the "butcher" type of wrap, requiring about 80 sq ft per 100 pounds of meat wrapped.

To make a "druggist's wrap," place the product in the center of the paper. Bring the two longest sides of the paper together over the product and fold these edges over about one inch. Fold again as many times as necessary to bring the paper tight and flat against the top of the product. To avoid waste of wrapping material, the paper should be only long enough to make two folds.

Turn the package over and fold end corners toward each other; then fold the ends over, stretch tight, and secure with locker tape or twine. Tape will make a tighter seal. Plain aluminum foil needs no tape or twine because the ends can be folded and rolled tightly into place. When wrapping with foil, do not draw it too tight in making the top fold so that there will be enough material to press close around any irregular surfaces.

The "butcher wrap," commonly used at meat markets, is started by placing the product close to one corner of the paper. Then fold all sides over and over until all the paper is used. Secure with tape or twine. A single butcher wrap requires about 100 sq ft of material per 100 pounds of meat wrapped.

Locker plants use mostly 18 and 24-inch widths of papers, the 18-inch width being used in considerably larger volume. Some locker plants using the druggist's type of wrap make much use of a 15-inch width. Foil is used mostly in 12, 15, and 18-inch widths as it requires less material to close the ends properly.

A dry finish butcher paper (often known as "steak" paper) is commonly placed between layers of meat and fish so that the layers can be separated while still frozen. Any waxed locker-paper or other frozen food wrapping material will serve this purpose. Paper folded double, rather than single sheets, will make separation easy. Package all cuts flat, so that cooking can be started, if desired, before the meat is thawed out. Do not roll steaks.

Packaging Costs

Locker plants.—The cost of the various sheet materials is now so competitive that practically all of them fall within a rather

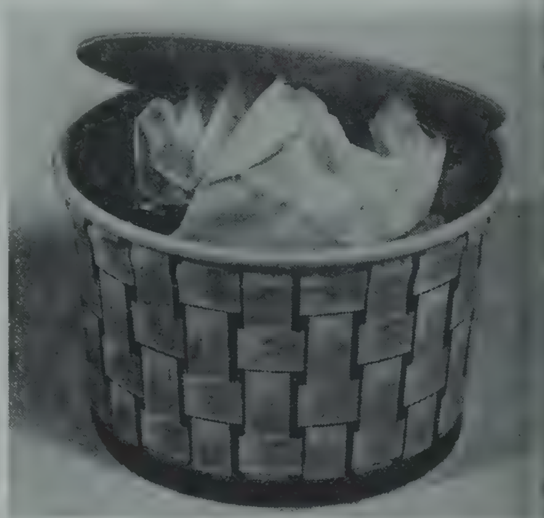

Fig. 10. A wad of waxed locker paper under the cover keeps peaches, sweet cherries, and apricots immersed and helps to prevent discoloration.

narrow range in terms of cost per pound of meat wrapped. Under average locker plant operation this cost is approximately 55 to 75 cents per 100 pounds of meat, hook weight.[23] These costs exclude a single wrap of waxed locker paper which is not recognized as an effective wrap.

The selection of a wrapping material, on a cost basis, rests largely on the differences in labor costs involved and on necessary investment in equipment. No published data are available on these cost factors with respect to the different types of wrapping materials.

Home packaging.—The cost of wrapping and freezing meat at home is higher than generally recognized. Wrapping material

purchased in retail rolls will cost about $1.40 to $1.85 per 100 pounds of meat wrapped. When the freezing cost is added (about 11 kwhr), the total cost is not much lower than the price charged by many locker plants for cutting, grinding, wrapping and freezing the meat, and marking the packages.

Containers for Commercially Frozen Foods

Many different types of containers are used for the commercial packing of frozen foods. Most types are adapted for use in automatic machines which wrap containers at speeds up to 150 cartons per minute. Illustrated descriptions of large numbers of such containers have been published.[1] They include the following types:

(1) Carton with printed, waxed-paper overwrap
(2) Carton with printed cellophane overwrap
(3) Carton with printed foil overwrap
(4) Printed carton with cellophane overwrap
(5) Printed carton containing film-wrapped product
(6) Cylindrical, cup, or tub containers, printed or with printed top label
(7) Carton with metal ends, printed or with printed overwrap
(8) Cellophane or Pliofilm bag or wrap printed or with printed tab
(9) Aluminum foil or tray, with printed overwrap or top label
(10) Metal can (for institutional sizes and for concentrated fruit juices). Labels showing life-like vignettes of the foods themselves are predominant.

Containers for Home and Locker Plant Use

Most types of frozen food containers now on the market provide satisfactory protection to the food when used according to instructions. Choice of containers is based largely on cost, reusability, convenience for use, space occupied in the locker or home freezer, and convenience for stacking. Warehouse space occupied by the unfilled containers must be considered by dealers. Space occupied by the various shapes of containers after packing and freezing is approximately as follows:

	No. of containers per cu ft (pint size)
Rectangular	40
Cylindrical or tub	27 to 30
Glass freezer jars	25

Containers having lids are preferred for fruits that darken easily on exposure to air

Fig. 11. Polyethylene bags are easy to fill (right). Bags made of transparent film may be closed by twisting and tying the tops with soft twine, rubber binders, or Twist-ems.

Fig. 12. Showing use of Twist-ems to close bags of transparent film. They make a tight seal and are easy to remove without damage to the bag.

(apricots, peaches, sweet cherries) in order to facilitate the submerging of the top slices in the liquid. This is done by placing under the lid a generous piece of crumpled sheet material of suitable moisture resistance.

The effectiveness of the closure of the various types of containers may be observed by placing a very small amount of dry ice inside the empty container and submerging it in water.

In general, foods (except vegetables) should be thawed in the original container before it is opened.

There are at least seven distinct types of containers now in use:

(1) Paperboard containers, waxed or with vapor-proof inside coating
(2) Lacquered metal cans
(3) Transparent plastic containers (rigid type)
(4) Aluminum trays with covers
(5) Bags, non-shrinkable with or without outside cartons
(6) Bags, shrinkable plastic
(7) Glass jars

In addition, it is not uncommon practice in some areas to freeze fish and cut poultry in a block of ice by packing the product in a bread tin or other suitable container and covering with water. This method is satisfactory but gives no better protection than good packaging.

(1) *Paperboard containers.*—Many advances have been made in the manufacture of paper board containers. Corner leaks in rectangular types have been eliminated by dip-coating the containers after they are formed. In some instances, waxing has been superseded by the use of a plastic inside coating. Closures have been improved. In general, these containers are easy to handle and fill and they provide effective protection for frozen foods.

(2) *Lacquered metal cans.*—Metal cans with tight lids provide excellent protection for frozen foods. Berries should be frozen rapidly to avoid possible discoloration of some types of fruit, especially if the inside coating has become scratched through reuse.

(3) *Transparent plastic containers.*—A recently developed rigid type of plastic container is available, made of transparent polystyrene with a polyethylene cover. Polystyrene becomes brittle at 0 F and breakage has been experienced occasionally as a result of the expansion of tightly

packed foods during the freezing process.

(4) *Aluminum trays.*—These containers, when properly sealed, provide excellent protection for frozen foods. They are especially adapted for pre-cooked frozen foods which may be re-heated in the original container and they have found wide commercial acceptance in the sale of such products. A semi-automatic machine is available for sealing the lids in place at the rate of about 6 per minute; a hand machine also is available that will fasten 3 to 4 covers per minute.

Foods may be cooked in these trays before freezing, or after removal from zero storage. When the food is cooked in the tray before freezing, do not fasten the lid until after the food has been cooked and cooled. If desired, the tray may be covered lightly during the cooking period. For best retention of flavor, the cover should be vented or removed when re-heating roast meat or poultry that was cooked uncovered in dry heat.

With proper use, the trays may be re-used several times. New lids may be purchased separately.

(5) *Bags (non-shrinkable).*—Many types and sizes of bag containers are on the market for use with or without outside cartons. Cellophane, Pliofilm, and certain paper bags require a protective outside carton but some polyethylene bags are strong and durable enough to be used without cartons. Polyethylene bags also may be placed inside inexpensive Kraft paper bags for protection in handling and for ease of marking. The popularity of polyethylene bags is rapidly increasing due to their durability during handling and storage at 0 F and because they may easily be filled without the use of a special funnel. These bags are made both with and without gussets; the latter type is recommended for liquid packs because of the greater certainty of a water-tight seal at the bottom end of the bag. Bags should be tested with water before they are used for liquid packs.

The proper temperature for heat-sealing the various types of bags is critical within 30 F or less. If the temperature is not carefully controlled the sealing operation may partially impair the protective value of the material. The sealing temperature for cellophane and Pliofilm is much less critical than for polyethylene. Automatic and semi-automatic heat-sealing equipment is available.

Under home and locker plant conditions, the film bags may be closed satisfactorily by twisting the tops and tying with soft twine. In some cases a better seal may be made by bending over the twisted tops in "goose neck" fashion before tying. Small rubber binders may be used instead of twine, although the rubber may be subject to deterioration after 6 months at 0 F. An easy and effective method is to secure the twisted tops with Twist-ems, which are inexpensive paper and wire strips widely used by florists and market gardeners. The effectiveness of twisting and tying may easily be demonstrated by placing a very small piece of dry ice in an empty bag before tying and checking the closure under water after some pressure has built up.

Because polyethylene is transparent, marking of the package may not be necessary (except at locker plants) when bags are used without an overwrap. Otherwise, a brush pen may be used satisfactorily on most polyethylene bags. With some foods, a label may be placed inside the bag before it is closed.

(6) *Bags (shrinkable).*—The only bag shrinkable to less than its original size at present available is a transparent plastic film of specially formulated vinylidene copolymer (Cry-O-Rap). This film is an effective barrier to oxygen and moisture-vapor. The food is placed in the bag, vacuum is applied to reduce air pockets, the bag is heat-sealed and then dipped momentarily in water at 190 to 200 F to shrink the plastic film. Shrinkage is about 30 percent. This process (Cry-O-Vac) results in a very tight, clinging wrap. An investment of about $200 is necessary for the proper application of these bags. Some locker operators fabricate their own equipment at about half this cost.

(7) *Glass jars.*—Special glass freezer jars are available that are more resistant than ordinary canning jars to breakage. In some areas there is considerable reluctance on the part of locker operators to the use of glass containers by patrons as a

result of unhappy experiences with the use of narrow top canning jars. However, the modern glass jar is more durable and survey data[2] now show that many locker plants are selling glass containers. Only wide-mouth freezer or canning jars should be used. In some cases an undesirable odor has been noted from the rubber seal of some freezer jars.

Glass is an exceptionally good barrier to oxygen and moisture-vapor. Glass jars are particularly desirable for the short-time storage of left-overs, because of their reusability.

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If you searched this chapter for something which was not found in it, please let the editors know.

12. FROZEN FRUIT JUICE CONCENTRATES

I. Introduction

SINCE 1945 frozen fruit juice concentrates have developed into an important item of consumer purchases in the United States to the extent that at the present time they comprise the largest single item in the frozen food market. Orange juice concentrate is the most important, and essentially all process development in the field was based upon this material. Today the techniques are extended, with proper modifications, to an increasing number of products including other citrus juices, apple juice, grape juice, pineapple juice, and many others.

The essential requirement for a fruit juice concentration process is to provide for the economical evaporation of water at temperatures which do not cause the deterioration of any of the necessary and desirable properties of the juice.

II. History

Prior to the period of intensive process development, specifically aimed at fruit juices, concentrates were prepared in vacuum pan concentrators. This type of equipment was conventionally used for less heat sensitive materials.

It was operated at relatively high temperatures at a vacuum of 29 inches of mercury or less. The material being concentrated was not agitated sufficiently to prevent overheating. Fundamentally, this process failed to meet the requirements for the production of high quality juice concentrate regardless of any economic considerations, and other processes were sought.

Gore[1] and others developed a method for concentrating juices by freezing which, in principle, is identical to the homely method of concentrating "applejack." These juices are a mixture of constituents and therefore do not have a sharp freezing point. Of the constituents, water is the one present in largest concentration and it also has the highest freezing point. As the temperature is lowered, pure water crystallizes progressively, leaving a liquid residue with a progressively higher concentration of fruit juice solids. Mechanical separation yields ice and concentrate.

The method used by Gore was to freeze 50-gallon drums of juice in large baths. The drum was then put into a warm bath to free the cake which was then crushed. The crushed juice concentrate-ice mixture was then centrifuged, separating the liquid concentrate from the ice which was discarded.

While this method gave a good quality product, losses in soluble solids were relatively high, the process was cumbersome due to the handling requirements, and low temperatures were needed. Because of these factors and the inadequacy of facilities for distributing high quality frozen products, this early attempt to make high quality juice concentrate was not a financial success.

With the application of industrial engineering to frozen foods in general, by Birdseye frosted foods, and with the growth of

EDWARD G. HELLIER, Co-Author Chapter 12. Born 11/2/17 in Rockland, Maine. Educated at Massachusetts Inst. of Technology, Cambridge, Mass., BS, 1940. Formerly Asst. Supt. for American Cyanamid Company, 1940–43; Director of Dehydration Dept., National Research Corp., Cambridge, Mass., since 1943.
Author "Continuous High Vacuum Drying," published in *Food Ind.*, 1949.
At present Director of Dehydration Dept., National Research Corp., Cambridge, Mass.

HAROLD C. WEINGARTNER, Co-Author Chapter 12. Born 2/6/18 in Aurora, Illinois. Educated at University of Illinois, BS 1939; MS 1940. Formerly with Research Dept., Standard Oil Company (Indiana), 1940–41; NDRC, Division 10, University of Illinois, 1941–45; Chief Engineer, National Research Corporation, since 1945.
Author "Design of High Vacuum Engineered Plants," published in *Ind. and Engrg. Chem.*, vol. 40, no. 5.
Member, Amer. Inst. of Chemical Engineers.
At present Chief Engineer, National Research Corporation, Cambridge, Mass.

frozen food lockers and distribution outlets, the frozen food business expanded greatly during the early 1940's. In 1946–1947 National Research Corporation (through Vacuum Foods Corporation—now called Minute Maid Corporation) and Birdseye frosted foods brought forth high quality orange juice concentrates. The consumer acceptance of these products, after a slow start, increased with remarkable rapidity and contributed importantly to the expansion of the frozen foods business.

These concentrates were made by evaporating the water in the juice at temperatures and pressures lower than those used in the vacuum pan concentrators. Vapor condensation temperatures were significantly higher than those used in the freeze-concentration process. The growth of engineering know-how through wartime activities made large commercial scale high vacuum operation feasible. These high vacuum processes permitted the conversion of large quantities of orange juice to a reasonably priced high quality concentrate with a minimum of labor and loss of material.

III. Food Technology

The delicate flavors and aromas of fruits are deteriorated by the high temperatures associated with the usual canning operations. While these methods of canning alter the flavors of all plant produce, it is keenly noticed in the flavors of fruits which are available, fresh and ripe, to the consumer such as oranges, grapefruit, apples, etc. It is true that for other fruits such as pineapple the flavor of the canned product rather than the flavor of fresh fruit is definitive for most of the consumers in this country. The low temperature concentration processes provide products having a flavor equivalent to tree-ripened fruit and containing 90% of the vitamin content of fresh juice.[2]

The flavors and aromas of fruit also break down during storage at room temperature. For this reason the fruit juice concentrates are stored and distributed at low temperatures. This further prevents changes in color and consistency.

In order to control product flavor it is customary to concentrate to a higher degree than that in the marketed product. The concentrate is then blended with fresh juice. Following this it is frequently chilled to a semi-solid, canned, and put in low temperature rooms for final chilling and storage. Since juice flavor may vary over the fruit season it is possible to control flavor by blending concentrates from different seasonal periods. Similarly juices from different varieties of the same fruit or juices from different kinds of fruit may be blended.

While it is true that frozen fresh juice could be marketed, the large bulk of associated water which would necessarily be frozen, stored, and distributed makes this economically unfeasible. This, in itself, justifies the concentration of juices.

Quite clearly, the economy of distributing frozen concentrate as compared with that for fresh juice is dependent upon the degree of concentration in the distributed product. The industry has established what appears to be a practical optimum which is called a 3 to 1 concentrate. This means that to one volume of concentrate three volumes of water are added to effect reconstitution or, in other words, about three quarters of the weight of the fresh juice is removed. Only one quarter of the weight of the fresh juice need be frozen, stored, distributed, and carried home. The economies in this are obvious. Compared to frozen fresh juice the lowered volume of the juice to be distributed means that smaller cans can be used requiring less freezer space both in stores and homes.

Since the concentrate is in fact a concentrated solution, its ultimate freezing point is lower than that of water, so much lower that at the temperatures of most frozen food cabinets it exists as a slush rather than a solid cake of ice. This semi-solid condition allows the easy removal of product from the can.

IV. Fundamental Principles

The two major methods for the production of fruit juice concentrates are (1) freezing followed by mechanical separation of concentrate and ice, and (2) evaporation at low temperatures.

A. Freezing and Mechanical Separation

This method, at first glance, would seem to have the great advantage of requiring

the transfer of latent heat of fusion rather than the higher latent heat of evaporation as is required in the evaporation process. The ratio of heat of fusion to heat of evaporation for water is about 1/7. This saving on energy input is diminished by the necessity for successive freezings plus the increase in energy required per unit of water frozen, since the temperatures required are much lower than those used in evaporative concentration. This advantage is further diminished by the handling problems.

Although the attractiveness of this process may some day be increased by continuously freezing and pressing the juice-ice mixtures it is true that at the present time nearly all of the frozen fruit juice concentrates are produced by low temperature evaporation.

B. Low Temperature Evaporation

In this process filtered juice is fed into the vacuum system. First of all dissolved gases flash off. Then the juice is fed to the top of a vertical heat exchanger (evaporator). As it passes down the heat exchanger, either in film-type or flooded-type flow, it is heated and water evaporates at a temperature corresponding to the pressure in the evaporator. For orange juice this temperature is usually between 50 F and 70 F at pressures of around 10–30 mm mercury absolute.

The vapor generated is removed either by condensing it at the pressure of the system and pumping it out as a liquid or by pumping it out of the system and compressing it to a higher pressure, following which it may be condensed or cycled back to heat the evaporator.

The earliest installations employed a series of wetted wall evaporators all operating at essentially the same pressure (single effect). Heat was supplied by hot water heated by a boiler and the condenser cooling water carrying the heat of condensation was run down the drain.

The desirability of reclaiming the heat of condensation for use in further evaporation was soon recognized and the principle of the heat pump was put into effect.[3] Further economies were realized by using multiple effect systems in which successive evaporators are maintained at lower and lower pressures, and consequently lower temperatures, thereby permitting vapor from the first evaporator (first effect) to vaporize the liquid in the second evaporator (second effect) and the vapor from the second to vaporize water from the third evaporator (third effect) and so on. The implications of multiple effect evaporation are these: (1) since theoretically a pound of steam evaporates a pound of water, and since this in turn evaporates another pound of water, etc., the total amount of water evaporated per pound of steam (or equivalent energy) supplied to the first effect is N where N is the number of effects, and (2) the available temperature differential across any effect is 1/N times the temperature difference for a single effect system, and therefore the area of the heat transfer surface must be adjusted accordingly.

At the present time the heat pump principle is in general use in conjunction with single, double, and triple effect systems. The basic principle of the heat pump is that the temperature level of a heat carrying medium is raised by doing mechanical work on the medium such as the adiabatic compression of gases and vapors. Heat pump systems in use for juice concentration either make use of (a) refrigeration systems in which a centrifugal or reciprocating compressor boosts the heat level in the refrigerant, or (b) thermocompressor systems in which booster type steam ejectors boost the heat level of water vapor. However it is done, a net amount of energy equivalent to the work done is added to the system and must be dissipated to maintain a steady state.

Examples of the use of the heat pump follow, together with their relative advantages and disadvantages.

1. Direct Refrigerant Contact

Fig. 1 shows a schematic system of concentration in which hot refrigerant gas is used to supply the heat for the evaporation of juice. Conversely the juice evaporator acts as the refrigerant condenser (high side). The water vapor is condensed by the evaporating liquid refrigerant in a shell and tube type condenser. Conversely the water vapor heats the refrigerant (low side). The refrigerant is returned to the suction of the compressor unit and the cycle is repeated. The evaporator, for simplicity, is shown as

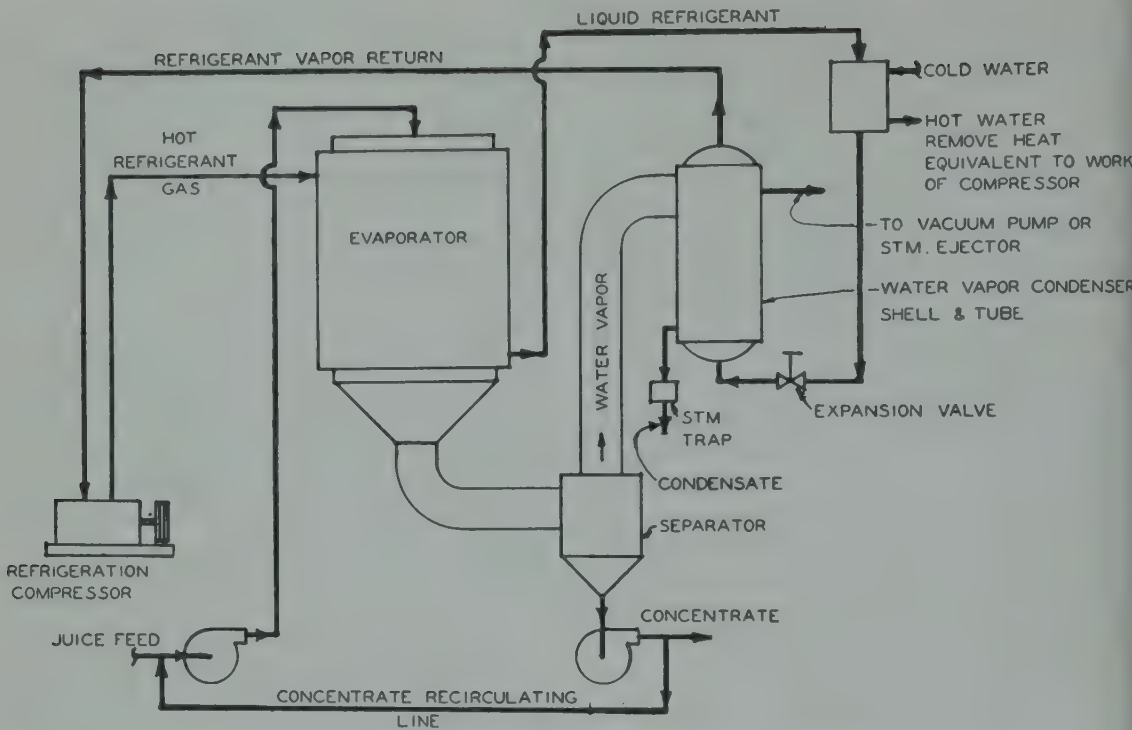

Fig. 1. System of Concentration Using Heat Pump Principle—Direct Refrigerant Contact.

a single effect with means for recirculating the juice. Variations may employ multiple effects, or parallel single effects. Vapor and concentrate are separated, usually by an arrangement of cyclones and baffles. The concentrate is pumped out of the system and fed to the blending, chilling, canning, and freezing processes. The vapor is condensed and pumped out of the condenser to waste. The pressure in the system can be maintained by a relatively small steam ejector or a mechanical vacuum pump.

a. Advantages of this system are

(1) Very little cooling water or steam are required. This is of basic importance in most citrus producing areas. Steam is required only to maintain pressure and water to remove heat of compression.

(2) Equipment associated with cooling water and steam is minimized, saving space and expense.

(3) Since the refrigerant vapor directly heats the juice and cools the vapor, a minimum temperature differential from refrigerant to juice can be employed. This means that for a given juice temperature the temperature of the hot refrigerant can be at a minimum and that of the cold refrigerant in the condenser can be at a maximum. This requires minimum energy input to the compressor.

b. Disadvantages of this system are

(1) Self contained packaged refrigeration units cannot be used. The refrigeration systems, controls, and instrumentation must be specifically designed for the particular installation.

(2) Refrigerant hold up is relatively high.

(3) Evaporating equipment must be constructed to withstand refrigerant pressures. Any leak in evaporators is in danger of contaminating juice with refrigerant.

(4) Refrigerant lines are relatively long.

2. Indirect Refrigerant Contact

Fig. 2 shows a schematic system of concentration which, though similar to that shown in Fig. 1, differs in the following ways: (a) the juice is heated by circulated hot water, which in turn is heated by the hot refrigerant gases (high side). (b) The vapor from the juice is condensed by direct contact with cold water in a water jet condenser, the water having been cooled

by the boiling refrigerant (low side). The juice cycle is the same as in Fig. 1 except that the water vapor is directly and intimately mixed and condensed in cold water. The condensate is drawn from the hot well. The pressure is maintained by a relatively small steam ejector or mechanical vacuum pump. Note that the essential difference lies in interposing water as a heat transfer medium between the hot refrigerant and the juice, and between the vapor and the cold refrigerant.

a. Advantages of this system are

(1) A centrally located standard packaged refrigeration unit can be used. Controls and instrumentation can be standard.

(2) Refrigerant lines are short and hold up is low.

(3) Evaporators need not be designed to hold refrigerant.

(4) No danger of refrigerant contaminating the juice.

(5) Very little steam or water are required. Steam is needed only to maintain pressure, and water only to remove heat of compression.

b. Disadvantages of this unit are

(1) Because of the use of water as an intermediate heat transfer medium the hot refrigerant gas must be hotter and the cold refrigerant must be colder than in Fig. 1. The suction to discharge temperature spread on the refrigeration unit is greater; therefore the energy input to the compressor per pound of water evaporated is greater than for Fig. 1.

(2) Equipment for handling water streams is required for this process which is not required in Fig. 1.

3. Vapor Recompression-Thermo Compression

Fig. 3 shows a schematic system for concentration in which the vapor from the

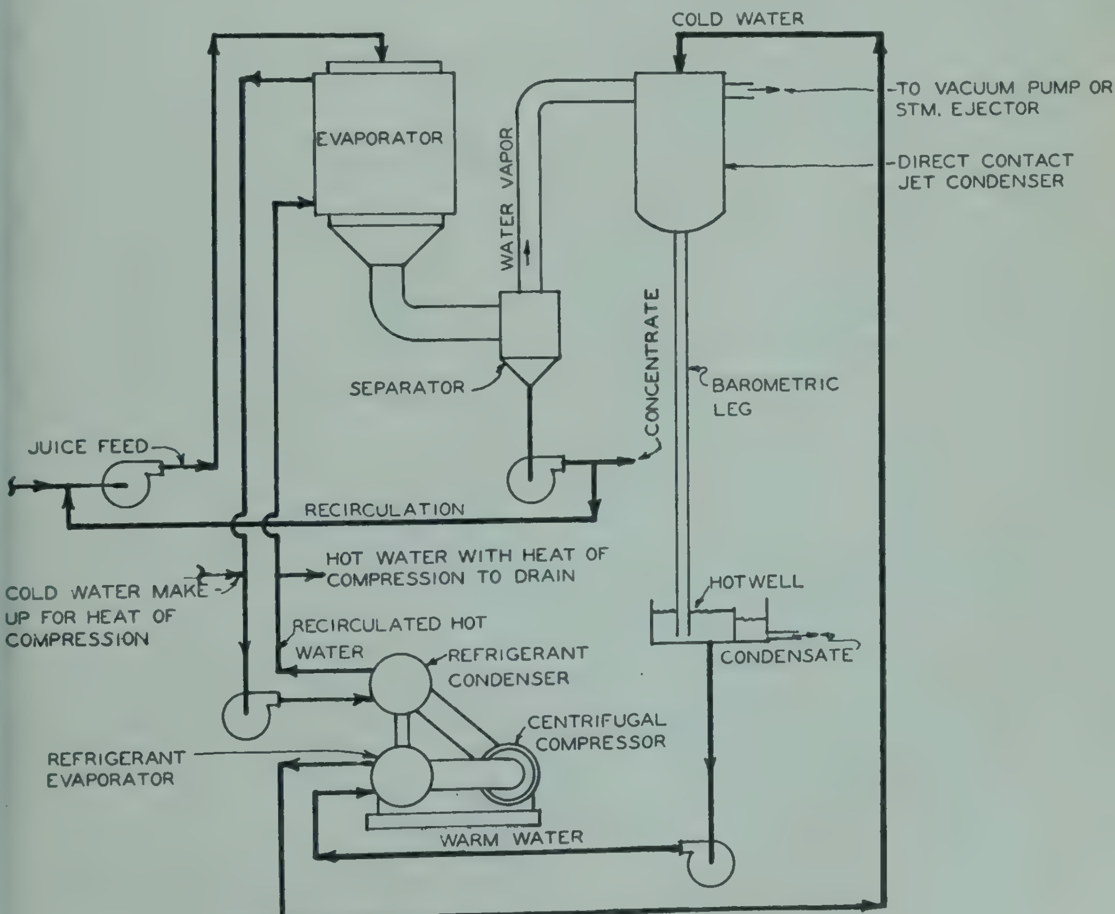

Fig. 2. System of Concentration Using Heat Pump Principle—Indirect Refrigerant.

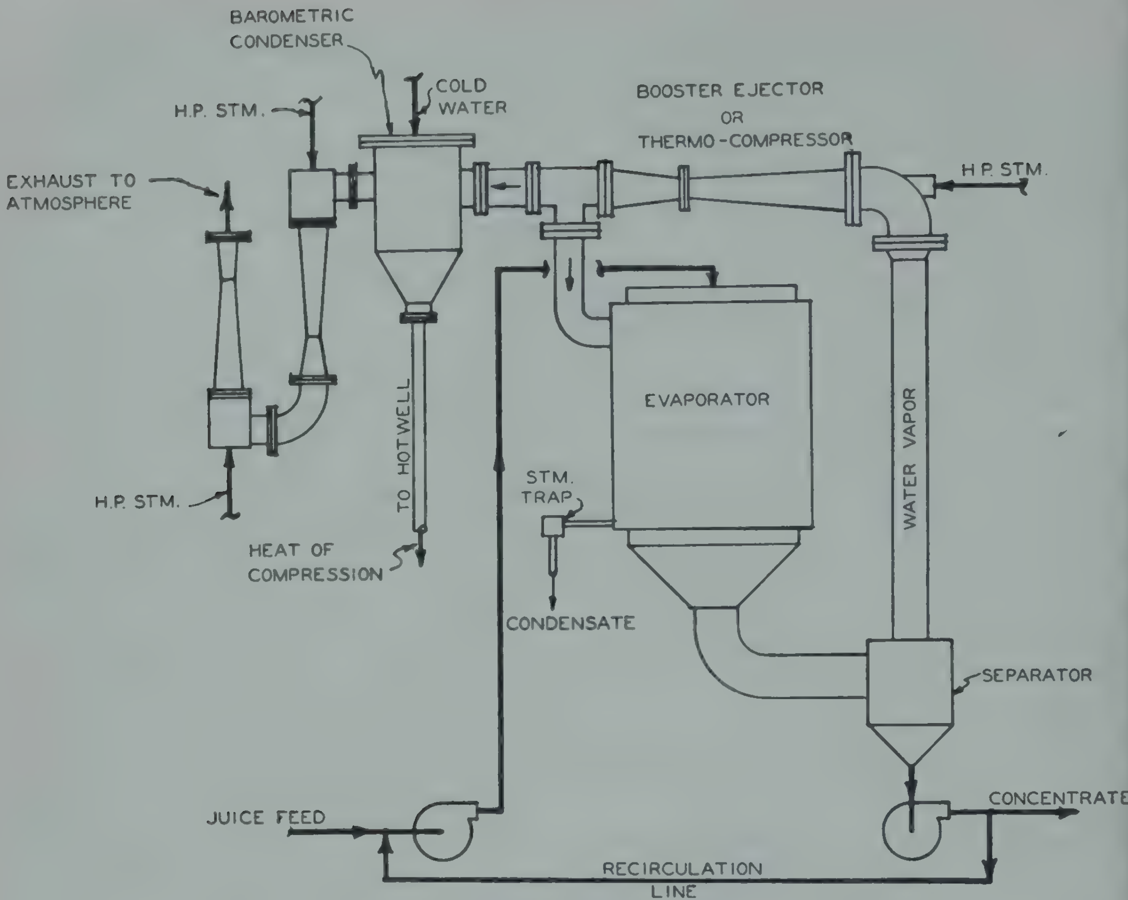

Fig. 3. System of Concentration Using Heat Pump Principle—Direct Vapor Re-Compression.

juice, instead of being condensed, is compressed to a higher temperature and pressure and used to evaporate more juice. The vapor is compressed by a booster steam ejector. It should be noted that this can also be accomplished by a mechanical compressor, but to date none are being used for fruit juice concentration in this country.

The evaporator is heated with steam and the condensate is pumped out to drain. The juice cycle is similar to Figs. 1 and 2 except that the vapor is recompressed and eventually leaves the system as condensate. The work of compression is supplied by the high pressure steam fed to the booster ejector.

a. Advantages of this system are

(1) The capital investment of steam ejectors is low compared to that for refrigeration systems.

(2) No low temperature condenser is required.

(3) No intermediate water circulation system is required.

b. Disadvantages of this system are

(1) More steam is required than either Figs. 1 or 2 and its use is relatively inefficient.

(2) More cooling water is needed than either Figs. 1 or 2.

These advantages and disadvantages are obviously relative. They are relative to product, plant location, cost of power, steam, and water, labor costs, and all the other factors that enter into the economics of plant design. Therefore no one system can here be designated as being superior. It is equally clear that variations can be played upon the process theme here developed.

An indication of the cost of operation for orange juice is given by the fact that the concentration phase can now be done for a cost, including amortization, of about 6¢ per gallon of concentrate, or ¼¢ per six-ounce can of concentrate.

Refrigeration is further used in the juice concentration process. The concentrate is frequently chilled to a slush in a continuous heat exchanger before canning. Following this it is cooled further in air blast freezers or cold storage rooms maintained near 0 F. Finally, refrigeration is used to maintain the low product temperature throughout the entire distribution process until it is finally consumed. These applications are standard and are thoroughly discussed in the literature.

V. Quality Control

Controls on the quality of frozen fruit juice concentrates must be exercised throughout the process. The details of criteria or standards may vary with the product, yet the kinds of standards involved can be illustrated by considering those set up for concentrated orange juice.[4]

A. Standards

United States standards for frozen concentrated orange juice have been established, effective 25 July 1949.[5] In brief, they require that the best grade of concentrate when reconstituted "possesses the appearance of fresh orange juice, possesses a very good color; is practically free from defects; possesses a very good flavor."

A very good color is a bright yellow to yellow-orange color typical of fresh orange juice.

Defects refer to particles of membrane, core, skin, seeds and portions thereof, recoverable oil and others.

Very good flavor refers to that typical of fine distinct fresh orange juice extracted from fresh mature sweet oranges. Further standards are set for the ratio of Brix value (a measure of sugar content) to the weight per cent of acid (as anhydrous citric acid). The range of standard Brix to acid ratios of Florida oranges is not less than 12:1 and not more than 18:1. The ratio for California oranges is not less than 10:1 nor more than 16:1.

The Brix value of the concentrate has been standardized at not less than 41.5 degrees and not greater than 43.5 degrees.

B. Selection of Fruits

The composition of orange juice varies with size and degree of maturity. It is not feasible to report these data here. Therefore publications containing them are listed in the bibliography.[6,7,8,9,10,11]

By means of periodic analyses fruit is selected as suitable for picking and concentration. The necessary criteria are established by federal and state standards as well as those which influence processing yields such as percent of juice in the fruit and per cent of solids in the juice.

C. Grading and Storing

Upon delivery the fruit is manually inspected. Damaged (cut or bruised) fruit and that showing any indication of spoilage is rejected. Deliveries are scheduled so that storage for more than a day or so is not required. Each load of fruit is tested for (a) juice yield reported in gallons per box, (b) Brix value, (c) total acid, and from (b) and (c) the Brix to acid ratio. Individual storage of each load, in separate wooden bins, permits this data to be used as a basis for subsequent blending operations or as a basis for rejecting a substandard load.

D. Washing

Prior to juice extraction the fruit is washed by immersion in an aqueous solution of a cleaning agent. During or following this it is scrubbed and then rinsed. The fruit is next treated with a bactericidal spray and then thoroughly rinsed.

E. Juice Extraction

After the juice is extracted by one of several conventional methods the peel oil content is measured. If it is found to exceed the value set by standards adjustments are made in the extraction process. To a certain extent oranges are blended before the juice is extracted. Brix and acid values for extracted juice are determined at frequent intervals (hourly) as a check and control of of the fresh fruit blending.

F. Bacteriological Tests

In addition to routine chemical and physical analyses made on incoming fruit and freshly extracted juice a bacteriological test is made to measure total organism count, mold count and a specific test for

the presence of the organism *E. Coli.* While, in itself, this organism is inoccuous, it indicates the presence of material and organisms of fecal origin. Should this organism be present more exhaustive tests are made to determine whether the juice is to be rejected or used.

After concentration a reconstituted sample of juice is again tested bacteriologically as well as chemically, physically and by taste.

If the total count of a final sample is over one million per cubic centimeter of reconstituted juice the product is not distributed. Actually the counts in operation run much lower (of the order of several thousand per cubic centimeter) and are taken as a measure of plant cleanliness. The concentration process is run on the basis of asepsis rather than antisepsis.

To this end the plant is routinely shut down for cleaning usually twice a week. In these periods all equipment is scrubbed and washed with a cleansing solution and thoroughly rinsed.

G. Blending

The general rule, at present, is to concentrate to more than 42 degrees Brix and then blend the concentrate with fresh juice to the standard Brix range of 41.5 to 43.5 degrees Brix. It is conventional to blend early and late season juice of the same crop of oranges through bulk storage of concentrate. This permits blending of sweet late season juice with tart sour early season juice and thus extends the processing season. Proper blending is done on the basis of the data noted in Section C. Frequently, simultaneously harvested fruit will represent the earlier stages of one crop and the later stages of another. These are blended by mixing oranges before juice extraction, again on the basis of data noted in Section C.

H. Final Quality

By careful control throughout the process the final quality can be assured and the final complete assessment confirms this. Here the reconstituted product is tested for Brix value, Brix/acid ratio, peel oil content, ascorbic acid (Vitamin C) content, flavor, and appearance. In the leading orange juice concentrating plants the testing is done by resident government representatives, and at present only the highest grade produce (U. S. Grade A) is marketed. Clearly, the importance of rejecting bad fruit before extraction cannot be overemphasized, for these may introduce factors which chemical washing and bactericides cannot quell. The processing equipment must permit sanitary operation and to this end it is desirable to provide for a minimum juice hold-up. Finally, company control must be all embracing and rigid. The standards set by an individual company must be higher than those set by government standards, especially those dealing with sanitation and cleanliness.

I. Distribution

Once the concentrate is canned, frozen and shipped, it is necessary to keep its storage temperature properly low. For orange juice the maximum desirable storage temperature is 0 F.

VI. Advantages to the Consumer

It is now possible for the consumer to get tree ripened quality, where heretofore he was limited to fruit which had been ripened in transport and storage. Due to scientific blending of early and late season juices, and since the juice product is now held at low temperatures in transport, distribution, and storage in the home, it is possible to have a uniform product of good quality at all times. Since the water and pulp of the fruit have been discarded at the point of growing, an over-all saving in transportation cost results, and this saving is passed on to the consumer. It is now possible to buy many other juices in concentrate form such as grape, grapefruit, tangerine, lime, cranberry, apple, pineapple, and many others. The cans are conveniently carried, stored, and opened.

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If you searched this chapter for something which was not found in it, please let the editors know.

SECTION II

COLD STORAGE PRACTICE

W. T. Pentzer, Associate Editor. Born 9/8/'01, in Lincoln, Nebraska. Educated at Oregon State College, BS, 1923; Iowa State College, MS, 1925. Formerly USDA Jr. Marketing Specialist, 1926–27; Assistant Plant Physiologist, 1927–35; Plant Physiologist, 1935–42; Senior Plant Physiologist, 1942–49; Principal Horticulturist, 1949 to date.

Author of Government and Experiment Station bulletins dealing with the pre-cooling, cold storage, and refrigeration in transit of fruits and vegetables; co-author Chapter 13, 1946 Applications Volume, ASRE Data Books; articles in *Refrig. Eng.*, "Food Industries," "Food Technology," and Proceedings of Amer. Soc. Hort. Science.

Member ASRE, Amer. Soc. Plant Physiologists; Amer. Soc. Hort. Science; Fellow, Amer. Assn. for Advancement of Science; Scientific Advisory Council of The Refrigeration Research Foundation; Sigma Xi.

At present Principal Horticulturist, Bureau Plant Industry, Soils and Agric. Engrg., U. S. Dept. of Agriculture, Beltsville, Md.

Chapter **Page**

13. COLD STORAGE PLANTS

THE location and choice of **size** of a cold storage plant calls for careful study and good judgment. The size is rated in cubic feet of **internal volume** of cooler and freezer spaces. Walls, stairs, elevator shafts, receiving and shipping floors, power plant, offices and the like are excluded when calculating rated volume.

Ten to fifteen years ago gross income ranged from 10 to 18 cents per year per rated cubic foot. During the last 6 years the gross income has varied between 23 and 28 cents. This increase is due principally to the high per cent of occupancy in freezer space caused by the exceptional growth of the fruit and vegetable freezing industry. The per cent of occupancy of cooler space has declined considerably in public warehouses due to a reduction in the storage of shell eggs and apples, which were formerly the principal commodities stored in coolers.

In large cities, plants under 500,000 cu ft are not likely to be profitable unless operated jointly with other services requiring refrigeration, as for instance, the manufacture and distribution of ice and pipeline refrigeration.

Location of Plants

1. A cold storage plant should be in **proximity to users,** public markets, produce dealers, commission merchants, meat packers, and the like. These businesses are generally concentrated in central locations close to railroad or water transportation facilities.

FRED OPHULS, Author Chapter 13. Born 8/18/76 in Crefeld, Germany. Educated at Stevens Institute of Technology, Hoboken, N. J., ME, 1897. Consulting Engineer in his own business since 1912.

Author of a number of articles published in *Refrig. Eng., Ice and Refrigeration,* and other periodicals. Also Chapter 11 in 1946 Applications Volume, ASRE Data Books. Member ASME; Fellow, ASRE; President, ASRE, 1921.

At present, Consulting Refrigerating Engineer, Fred Ophuls and Associates, New York, N. Y.

2. Location should be such that **cost of trucking** is a minimum.

3. Adequate **trackage** and **switching facilities** for handling refrigerator cars are essential.

4. Ample **platform space** for receiving and delivering goods from and to refrigerated trucks and refrigerated cars must be provided.

5. Location and building height should be such that the **cost of land and building** together is a minimum.

In the last 20 years building costs have climbed steadily. **Table 1** gives some information applying to a well designed and equipped house about the year 1929. The plant from which these costs were obtained contained a total of 2,200,000 cu ft of gross space, of which 1,680,000 cu ft are refrigerated.

Table 1. Initial Plant Investment
(1929 prices)

	Cost in cents per cu ft of refrigerated space	Cost in cents per cu ft of gross space
Building, including elevators, lighting, plumbing, engine room, etc.	35.2	26.9
Insulation and cold storage doors	5.1	3.9
Power plant, electrically driven, including all machinery in engine room	4.1	3.1
Sprinkler system, brine type	2.1	1.6
Brine piping in cold storage rooms	1.8	1.4
Fans, ducts, etc.	1.5	1.1
Total cost, not including land	49.8	38.0

Floor construction was designed for 225 lbs per sq ft of live load on freezer floors and 200 on cooler floors. Since then these costs have increased approximately 100% in the large cities.

In **Table 2,** Type A is the warehouse

type, having each floor insulated separately. Type B is the curtain wall type with provisions made for a complete insulated envelope enclosing the entire building with no insulation on intermediate floors. Good practice requires that coolers and freezer spaces are placed in separate buildings, generally adjacent to each other. The costs quoted are for the year 1932. These costs today should be doubled.

Table 2. Comparison of Building Costs
(1932 prices)

Type	Size	Cost, $	Cost, $ per sq ft
A	(1)	203,000.00	2.03
B	(1)	211,000.00	2.11
A	(2)	389,000.00	1.95
B	(2)	404,000.00	2.02
A	(3)	880,000.00	1.76
B	(3)	902,000.00	1.80

In this table, size (1) means a plant of 100 ft×167 ft, 5 stories and basement, having a gross floor area of 100,000 sq ft. Size (2) is 100 ft×200 ft, 9 stories and basement, having a gross floor area of 200,000 sq ft. Size (3) means 200 ft×240 ft, 9 stories and basement, having a gross floor area of 500,000 sq ft.

Cost data taken from the records of three large cold storage warehouses located in a territory where wage scales and power costs are the same, indicate a warehouse expense of 5.8 to 6.2 cents per 100 lb of goods handled and a power plant cost of 79.7 to 118.0 cents per ton day of refrigeration. These costs have increased since these figures were compiled. To arrive at present-day costs it will be necessary to add from 25 to 30 percent.

Arrangement of Plant

Division of cold storage space. The proportions of a public cold storage which should be devoted to cooler and freezer space respectively depend on the location of the house and the kinds of perishables to be stored. Due to the advent of **frozen foods** it has been found necessary to increase the ratio of freezer to cooler space. Present experience indicates that for normal times, in most localities, a large public cold storage plant should be provided with 66⅔ per cent of freezer space. It is good practice, where feasible, to arrange and equip some of the space so that it can be used as either cooler or freezer space.

The usual **location of freezers** is adjacent to coolers. The disadvantage of locating freezers above coolers is that it is impractical to provide a sufficient insulating seal between them to prevent excessively low temperatures in the cooler immediately underneath. For this reason the preferred arrangement is to locate the freezers and the coolers adjacent to each other. Whenever a freezer is located below a cooler a special thickness of insulating material must be put in the floor between, and even then it is necessary to pile the cooler goods on this floor carefully, using thick dunnage between the floor and the goods stored to obtain a sufficient air circulation so that too low a temperature will not reach the cooler goods. Forced air circulation may have to be applied to prevent freezing of the cooler goods.

Freezers should not be placed on the ground floor of the building or even on the first floor unless a careful investigation has shown that the water table of the surface water supply is at some distance below the bottom of the footings of the building and cannot reach that level when the well water supply is most plentiful. In other words, if there is any possibility that **water may collect** between the footings and below the bottom floor from any source whatsoever, the freezers must be placed above ground high enough so that this **water cannot freeze.** Building footings have been raised, floors lifted and insulation destroyed by the freezing of water that has found its way between the footings and underneath the basement or ground floor.

For a public cold storage the individual rooms should have as large an area as possible without incurring excessive structural cost. Single rooms having floor areas of 10,000 to 12,000 sq ft are not uncommon.

The usual allowance for **receiving and shipping floors,** including platforms, is 4 to 5 percent of the total cold storage floor

rea. While this represents the proper latform area needed, it is not always ossible to adhere to this rule. This floor, esides being a landing place for elevators nd stairways, as well as in- and out-going erishables, also contains a small office for he shipping clerk. Good practice requires nstalling one **elevator** for each 30,000 sq t of cold storage floor area. The minimum latform area must accommodate two rucks 30 in. × 60 in., and one or two torage men. An elevator 7 ft 6 in. × 7 ft in. will fill the requirements. The lifting apacity usually chosen is 1.5 to 2 tons nd the speed depends on the number of loors in the building, ranging from 75 to 50 ft per min. Elevators of larger floor rea are used with load capacities of 3 to 4 ons, but generally the small size with maximum speed suffice for efficient goods andling.

Construction Types

Fireproof construction is desirable to obtain low insurance rates and low depreciation. Slow-burning **mill construction** has been used formerly on account of its initial low cost. After 20 years or more, the upkeep becomes high. Failure occurs when woodwork is exposed to dampness, especially where beams and girders pass through the insulation and rest on the bearing walls or exterior columns, if any. It is now customary for repairing such structures to water-proof the ends of beams and girders where they pass through insulated enclosures.

Curtain wall construction as shown in Fig. 1 is distinguished by the fact that the exterior columns of the building are split, the outer walls being carried up independently of the rest of the building. The floors, roof and interior columns and the inner portion of the wall columns form one structure which is surrounded by the independent exterior walls. The insulation forms a continuous envelope, between the building proper and the outer shell, and is applied on the inner face of the outer shell.

Split columns are also often used at stair and elevator shafts and between the

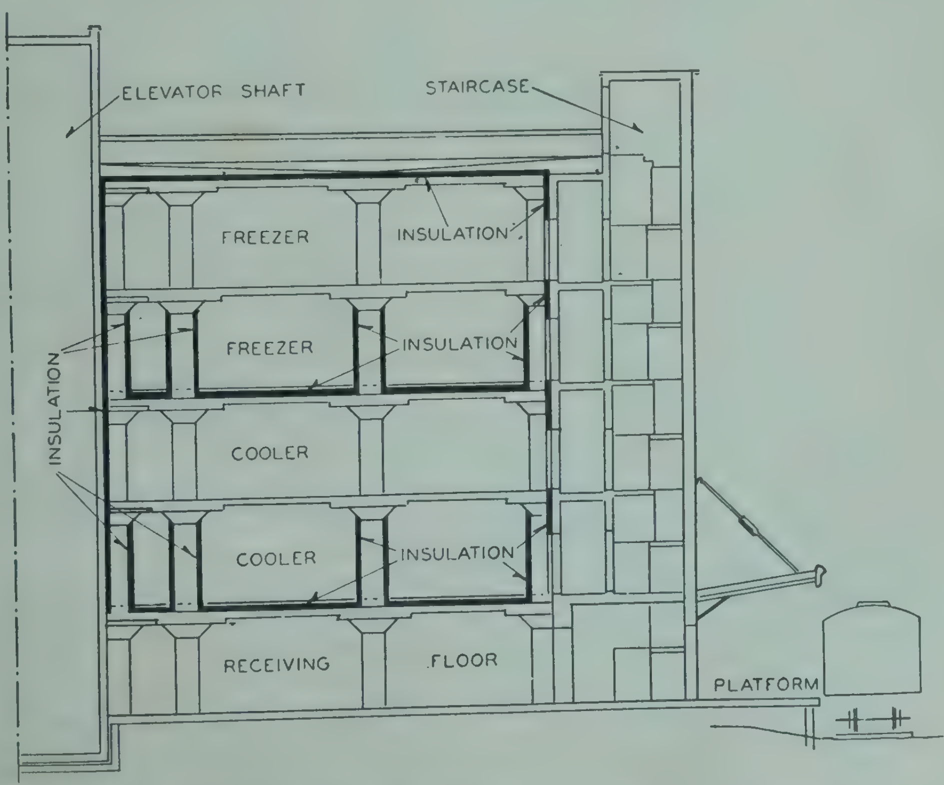

Fig. 1. Section of Typical Building with Curtain Wall Construction.

various sections of a large warehouse to carry out to the fullest extent the idea of an unbroken and unpierced insulation envelope. Even in this type of building compromises must be made, as it is impossible not to pierce the insulation envelope with the building construction at some points.

While insulation for buildings of the curtain wall type is in most cases applied in sheets plastered to the curtain and partition walls, a number of buildings of this type have been insulated with regranulated cork or other loose insulating material. The insulating material is filled into the slots formed by the curtain wall and a partition wall erected at the edge of the floor slab between the floor and ceiling. This partition wall is generally constructed of brick and plastered with cement mortar on the room side. The loose insulating material must be carefully rammed down to prevent excessive settling.

The inner face of the curtain wall should be waterproofed to avoid infiltration of moisture as far as possible. The chief objection to this type of structure is the large space taken up by the partition walls and the loose insulating material. For equal heat leakage the thickness of loose material used must be somewhat greater than the thickness of, for instance, sheet cork insulation.

In buildings of more than about six stories in height, vertical expansion joints must be provided to allow for the unequal expansion and contraction. Moreover, fire walls and cut-offs are required between the various sections of the building, and also between the shipping floor and the cold storage space, to reduce fire hazard.

Insulated warehouse construction is shown in Fig. 2. The building design used is that of the usual fireproof warehouse, insulated as well as possible. A comparison of the designs outlined leaves no doubt that the curtain wall construction lends itself best for an economical application of the insulating materials, and offers fewer weak points in the insulation against the inflow of heat and moisture.

A disadvantage of the insulated warehouse type of construction is that where the wall insulation meets a floor, it must be carried out over the floor in a sealing strip, and a wearing surface put above it. This requires a heavier structure for an equal live load and is wasteful of space, as the floor thickness is increased by at least 7 in.

In buildings of the curtain wall type unbroken layers of insulating material may be found on walls from 50 to 100 or more ft high. Such height of unsupported insulation will give trouble unless it is braced at every floor either by corbling out the curtain wall, or, where this is not feasible, by providing a horizontal wooden or steel rail against the wall side of the insulation, securing this rail to the curtain walls by bolts or anchors.

Comparing the structures of Fig. 1 and Fig. 2 for a cold storage of 1,000,000 net cu ft, the gross volume is 1,250,000 cu ft for the curtain wall type, 1,312,500 cu ft for the warehouse type, or an increase of 5 percent. On a basis of one-half freezer and one-half cooler space, proper insulation requires about 535,000 board feet of cork with curtain wall construction and about 840,000 board feet with the warehouse construction. Including the concrete wearing surface on top of the insulation in the warehouse type, the cost of insulating is approximately twice as great as for the curtain wall type.

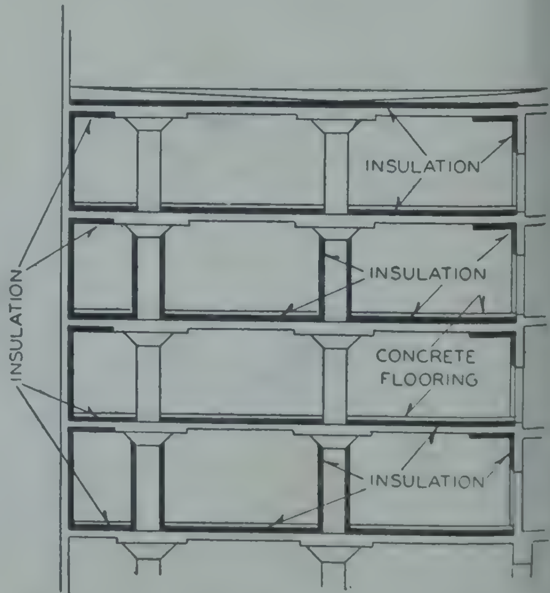

Fig. 2. Cold Storage Warehouse Construction.

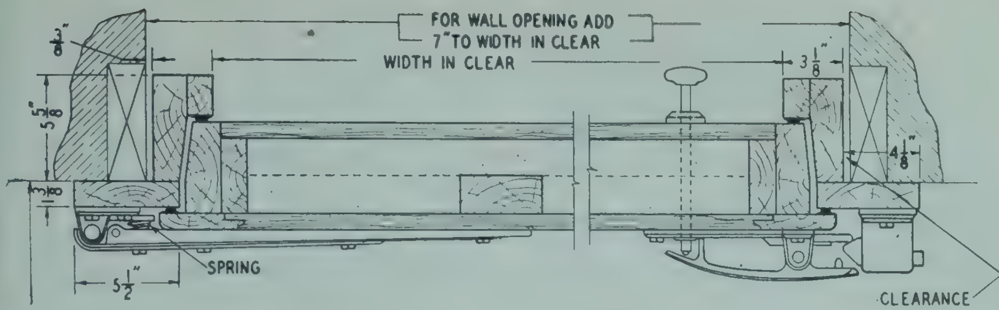

Fig. 3. Section of Typical Cold Storage Door.

An effective **flashing** for roofing against ɪrapet walls must be provided. It is ɛcessary to make the lap of the flashing at ast from 9 to 12 in. deep. For added fety one should waterproof all the interior and exterior exposed surfaces of the ɪrapet walls. In any cold storage building akage at this point will cause serious amage to the insulation.

The method and materials used to pply **insulating materials** to walls, floors ıd ceilings need careful consideration. he main object to be achieved is to ecure an insulation envelope which offers ıe greatest possible resistance to the ow of water vapor from the surrounding ir into the freezer or cooler. This water apor destroys the insulating materials, ıcreases the heat transfer through them nd is one of the principal sources of the rost accumulation on the cooling surfaces.

Experience with various designs and inds of insulating material applied to reigerated spaces indicates definitely that he greater the care used in its installation nd in its protection from damage through xterior causes the longer will be its life and ısefulness. More wall, floor and roof insuation has been damaged by seepage of water through concrete or brick walls and defective or badly designed flashing than rom water vapor penetration from the outer air. During the winter months this moisture will freeze and in expanding push vapor barrier and insulation off the wall, breaking the vapor barrier and allowing access to the insulation material for further damage.

Most of the insulating materials are not vapor-proof. To overcome this deficiency a **mastic material** is used to cover the surfaces and secure the insulating materials to them. In time this mastic membrane cracks in places or has been applied in too thin a coating so that the water vapor finds its way through. Wherever possible one course of Foamglas, or a similar vapor-proof material, should be used. This material is vapor-proof and has a reasonably low coefficient of heat transfer.

Insulating materials should **not** be placed **on ceilings** but **on the floor above.** If that construction is not feasible and the insulation must be installed on a concrete ceiling, the first layer should contain wooden strips fastened to the ceiling to which the insulation can be securely nailed besides being glued in place with a mastic emulsion.

The customary allowance for **live load** on all floors of a cold storage house is 250 lb per sq ft.

The economical **height** from floor to ceiling in a house not equipped with sprinklers and where man power is used for piling and handling of perishables is 10 ft 0 in. A building with sprinklers to maintain this economical clear height, must be designed with additional height to allow for the sprinkler system. This requirement brings the floor-to-ceiling height to from 10 ft 8 in. to 11 ft 4 in., depending on the width and length of the room and the design of the sprinklers.

In recent years mechanical handling of cold storage goods has made considerable progress. The use of pallets and fork trucks make it possible to move a considerable number of packages in one operation from the refrigerator car or refrigerated truck to their storage location in the freezer or cooler. Here the pallet loads can be stacked

one above the other as high as the ceiling will permit or, what is more important, as high as the type of packing will permit without deforming it and crushing its contents.

Clear ceiling heights of from 14 to 18 feet have been advocated and used in the design of some recently built cold storage warehouses. For freezer goods high stacking is generally permissible. However, packages containing frozen vegetables, or, as a matter of fact, any perishables which cannot be closely packed to form a solid block when frozen, cannot be stacked on pallets to advantage in these high ceiling rooms. For these frozen products the 10 ft room allows the maintenance of the highest percentage of occupancy.

For cooler goods high stacking is particularly precarious. Shell eggs packed in the customary wooden boxes cannot be stacked 14 to 18 feet high. Boxes so stacked will be crushed and the eggs damaged. The same applies to all cooler commodities packed in crates, bags, etc. If intermediate supports are furnished, two tiers of goods on pallets can be stacked one above the other but the cost of handling the goods increases.

The designer of a new cold storage warehouse today must face some problems for which no definite answers have been found. Mechanical handling and design for it is indicated. When mechanical handling is installed, obstructions hung from the ceiling and attached to the walls cannot be permitted.

Most of the existing cold storage buildings are many stories high, their height generally being limited, especially in large cities, by law. Where land is cheap and adjacent to railroad and highway, one-story cold storage warehouses of the cheapest possible construction have been advocated and a few built. The advantages claimed for this design are: Ready access to the refrigerated spaces for goods coming in and going out, their prompt storage and delivery, and reduction in the man hours per ton of perishables handled. When comparing the area covered on the ground by a one-story warehouse equivalent to a multi-story building containing 1,000,000 to 2,000,000 net cu ft of storage space, these claims do not appear justified nor have they been confirmed.

For perishables held in intransit storage the location of the warehouse is not of great importance. Warehouses catering largely to local business find proximity to the trade desirable, otherwise long hauls by truck become excessive in cost for repairs and operation. The cost of the real estate where the warehouse should be located will determine whether a one-story or a multi-story structure must be built.

Fig. 3 shows typical section of an **in-fitting** cold storage door, such as is used for both coolers and freezers, varying the thickness of insulation. Special **overlapping** freezer doors with wide faced flanges are also used. These doors can be obtained in various standard sizes suitable for usual requirements. Where vestibule elevators are used, it is often desirable to install **two-leaf doors** on the receiving floor level for quick unloading of the elevator.

Window openings are not required in freezers, but are desirable in coolers. When used in coolers, two window openings should be provided in each cooler in opposite walls to provide cross ventilation. Window sash is not used in modern coolers, but the window openings are closed with **window plugs** which are a modified form of cold storage door.

The maintenance of **gaskets** on cold storage doors is important, particularly on freezer doors. Unless these gaskets are painted with some non-freeze solution such as one made of equal parts of alcohol and glycerine, the doors freeze to the jambs, making them difficult to open without damaging the gaskets. Sponge rubber gaskets are recommended.

Fire Protection

Ordinary sprinkler systems cannot be applied to refrigerated space without modification. Two types of modified systems are in use, the brine system, and the dry pipe system.

The **brine system** employs the ordinary sprinkler scheme, but the pipes in the refrigerated spaces are filled with calcium chloride brine instead of with water. When the system functions, the initial charge of

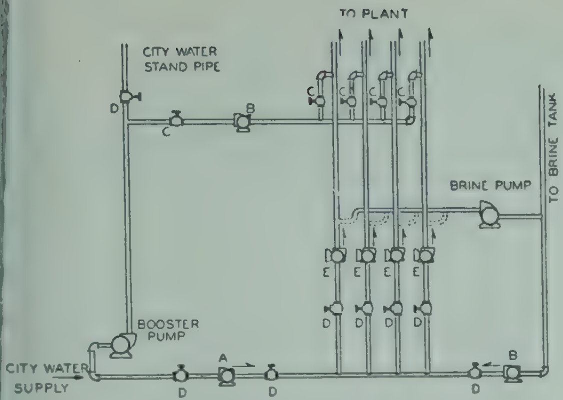

Fig. 4. Brine-Filled Sprinkler System.

A, B, E—check valves; C—valve normally closed; D—valve normally open.

brine leaves the pipes and is followed by water in the usual manner. The calcium chloride brine is strong enough that it will not freeze in the rooms maintained at the lowest temperature. Outline of such a system is shown in **Fig. 4.** The brine is maintained under greater pressure than the city water, and is sealed off from it by special check valves A and B. The individual distributing headers are sealed off by similar valves, C, and the distributing header pressure is maintained above the brine stand pipe pressure by a brine pump. In case of leakage of these valves, or their opening due to fire, pressure is built up in the clapper seat opening and an alarm is sounded. In case of fire, the brine pressure is immediately relieved and valve A feeds city water to the system. The booster pump can be used to pump city water to the plant at increased pressure through valve B, by manually opening the normally closed valves, C, on this line.

Two additional special **check valves** are installed in the city water supply line before it enters the plant to insure against brine flowing into the city water mains.

In the **dry pipe system** the sprinkler pipes in the refrigerated spaces are filled with dry compressed air. The water is sealed off from the compressed air by a special dry pipe valve. The air pressure, which is carefully controlled, keeps this valve closed so long as no sprinkler failure occurs. When a sprinkler plug melts, the air pressure is relieved and the water pressure forces the valve open and feeds water into the sprinkler system.

Performance of Plants

The actual **refrigerating capacity** necessary to take care of a cold storage warehouse can be determined in two ways, by using experience figures, or by calculating the heat load.

Using experience figures is somewhat dangerous, particularly in the case of the freezer work. The amount of fresh produce to be frozen at the plant, such as butter, broken eggs, poultry, etc., varies greatly with the business of customers and the location of the plant. Some of the tables which follow will, however, give an idea of the actual refrigeration produced in the existing plant. The storage warehouse from the operation of which these data were taken some years ago, occupies an entire city block having a superficial area of

Table 3. Seasonal Movement of Perishables In and Out of Cold Storage Plants

Month	In—Principal items	Out—Principal items
January	Nuts, meat	Apples, butter, eggs, meat
February	Fish, meat, berries	Apples, butter
March	Eggs, fish	Butter, meat
April	Eggs, fish, celery	Apples, butter
May	Eggs, berries	Berries, poultry
June	Eggs, butter, meat	Berries, meat, poultry
July	Eggs, butter, meat, berries, fish	Poultry, berries, butter, meat
August	Butter, fish, berries, meat	Butter, eggs, meat, poultry
September	Poultry, fish, meat, berries	Butter, eggs
October	Apples, fish, berries, meat, poultry	Eggs
November	Apples, poultry	Eggs, butter, meat
December	Nuts, celery, fish	Eggs, meat

Table 4. Actual Tonnage for Load of Plant Discussed

Month	Ammonia circulated, lb	Average refrigeration load, tons				
		Total	Freezer	Cooler	Per million cu ft of freezer	Per million cu ft of cooler
January	1,800,000	105	59	46	28	13
February	1,158,000	76	51	25	24	7
March	1,697,100	100	68	32	32	9
April	2,038,100	121	63	58	30	16
May	2,832,700	159	88	71	41	19
June	3,487,000	198	106	92	50	25
July	3,853,800	210	114	96	54	26
August	3,519,000	190	112	78	53	21
September	3,163,500	178	100	78	47	21
October	2,933,700	164	82	82	40	21
November	2,553,100	152	98	54	45	16
December	2,191,000	128	83	45	39	12
Average rate for year		148	85	63	40.3	17.2

about 59,250 sq ft. The gross cubic content of the buildings is approximately 9,000,000 cu ft, of which the net cold storage space represents 5,800,000 cu ft.

At that time this building contained 2,126,000 cu ft (36.7 percent) freezer space, and 3,674,000 cu ft (63.3 percent) cooler space. The nature of the perishable load for a typical year is as shown in **Table 3.**

A determination of the monthly average **refrigerating effect** required was made by measuring the quantities and temperature of liquid anhydrous ammonia flowing, from which **Table 4** was obtained.

The average maximum daily heat leakage through the insulating envelope into this building was calculated and is given in **Table 5.**

Comparing the refrigerating effect to overcome maximum **heat leakage** with the average refrigerating effect required for July, it is apparent that the average heat leakage into the refrigerated spaces through the enclosing insulated structure is only a part of the total refrigerating effect actually required. The total refrigerating work is made up of:

Heat leakage through insulation enclosure.

Vapor leakage through insulation enclosure.

Heat removed from perishables to reduce them to cooler or freezer temperatures.

Heat removed to freeze perishables.

Heat developed by perishables placed in cooler spaces.

Heat removed from air entering through open doors or brought in from outdoors.

Heat generated by lights and motors in the refrigerated spaces.

Heat given up by men working in the rooms.

The above items are mentioned in the approximate order of their magnitude, although refrigeration to overcome air and vapor infiltration may become a large factor if improperly designed equipment is used.

Table 5. Calculated Heat Leakage of Plant

	Exposed surface, sq ft	Heat flow, million Btu per day	Btu per sq ft per day	Tons
Coolers	155,793	14.22	91.3	49.5
Freezers	108,772	11.01	101.2	38.2
Total	264,565	25.23		87.7

An analysis of figures in Table 4 is necessary to make them of use to the designer. A segregation of the maximum refrigerating effect required in the freezers for the year appears in **Table 6.**

Table 6. Maximum Capacity Required of Freezers, Test Plant

		Ton-days
Total annual tonnage in the freezers (85 ×365)		31,000
Heat leakage into freezers	13,950	
Cooling frozen goods to room temp.	723	
Cooling goods to be frozen to room temp.	6,250	
Freezing poultry and game	6,530	
Freezing meats	1,140	
Freezing, miscellaneous	1,663	
Total	30,256	30,256
Balance, unaccounted for		744

Table 7. Analysis of Freezer Foods for Year, lb

	Fresh	Frozen
Poultry and game	24,582,489	12,291,245
Butter	6,031,096	2,000,000
Meat	2,843,670	315,963
Canned goods		6,180,000
Miscellaneous	355,350	39,483
Total	33,812,605	20,826,691

The balance approximately represents the refrigeration required to take care of lights, power, open doors, any heat that might be developed by the freezer goods in storage, etc. The weight of freezer goods received during the year is given in **Table 7.**

The refrigeration required for the cooler space is more difficult to calculate because the heat given up by the perishables while in storage is an appreciable item and information on this subject meager. To show how the cooler refrigeration is made up, the figures of **Table 8** are of interest.

For approximate estimations **Table 9** has been prepared from the foregoing by adding, for exceptional peaks and heavy loads, 15 percent to the actual refrigerating effect required for July. This applies both to freezer and cooler work, proportioning the heat leakage to the area of the exposed insulated surfaces, and the balance of the refrigeration required to the net volume of the cooler and freezer space respectively.

In the last few years most, if not all, public cold storage houses have increased the volume of the freezer space, so that this space often exceeds ⅔ of the available storage space. Most of this additional freezer space has been gained by the conversion of existing coolers to freezers. The increase in the supply and consumption of frozen foods or perishables of all kinds and the reduction in the volume of perishables offered for cooler storage has made this change necessary and a permanent requirement. When using the refrigerating effects given in Table 9, this fact must be taken into account and the figures corrected for the actual relation between freezer and cooler spaces.

Low Side Equipment

Two cooling systems are used in cold storage, the **direct,** in which refrigerant circulates in the space cooled, and the **indirect system,** in which brine is cooled by the refrigerant, the brine being circulated through its own heat absorbing system. For use in public cold storage houses

Table 8. Cooler Load Distribution

			Tons
Average daily refrigerating effect for the month of October			
Daily heat leakage for the month			21.2
Cooling of goods:	7,786,600 lb apples at 20 Btu	155,732,000 Btu	
	1,333,639 lb eggs at 16 Btu	21,338,224 Btu	
	1,906,968 lb misc. at 15 Btu	28,604,520 Btu	
Total	11,027,207 lb	205,674,744 Btu for 31 days or	23.0
In storage: 30,000,000 lb cooler goods (mostly apples) at about 35 Btu per lb per day			36.5
Heat given off by apples in cooling from 60 F to about 32 F, average rate of 2000 Btu per ton			1.3
			82.0

Table 9. Maximum Refrigerating Effect for Cold Storage Warehouses
(Space divided ⅓ freezers and ⅔ coolers)

Rating, million cu ft	Freezers million cu ft	Coolers million cu ft	Insulation area, sq ft Freezers	Insulation area, sq ft Coolers	Heat leakage, tons Freezers	Heat leakage, tons Coolers	Total load, tons Freezers	Total load, tons Coolers	Total load, tons Total
1	.333	.667	30,000	40,000	10.7	12.7	25.3	23.8	49.2
2	.667	1.333	45,300	63,600	15.9	20.2	45.1	42.4	87.5
3	1.000	2.000	61,800	96,600	21.8	30.7	65.5	63.9	129.4
4	1.333	2.667	75,300	107,400	26.5	34.2	84.7	78.5	163.2
5	1.667	3.333	86,800	123,500	30.5	39.3	103.3	94.6	197.9
5.8	2.126	3.674	108,772	155,793	38.2	49.5	123.2	112.5	235.7

the brine circulating system is preferred for the following reasons:

1. No claims can be upheld by the storers of perishables that the goods have been damaged by absorbing refrigerant odors escaping from defective piping.

2. The regulation of proper brine flow to maintain the required temperatures in the cold storage rooms is less difficult than the regulation of the refrigerant in the direct system. More uniform temperatures can be maintained.

3. There is no condensation drip from brine piping when in operation.

In justice to the direct expansion system of cooling, it must be pointed out that in a well constructed and maintained piping layout, leakage of the refrigerant is a rare, if not a negligible occurrence, particularly when most of the screwed and flanged joints are eliminated and welded joints used in their stead.

For distribution of refrigerated brine to the various heat absorbing units, the two-pipe system or the three-pipe system may be used.

The **three-pipe system,** shown in **Fig. 5,** is preferred because the cooling units do not become air bound. Since all the brine circulated has to pass the vent at the top of the system, air entrained in it is promptly removed.

The **two-pipe system** has the advantage of low first cost of installation.

The brine feed and return mains rise through the house in pipe shafts, or along the walls, or in the corners of the cold storage rooms passing from floor to floor. In the former case the mains must be insulated where they run outside of storage rooms. While the pipe shaft and the necessary insulation add to the first cost of the system, they will also serve for the distribution of electric wiring, etc. When brine mains are run vertically through the cold rooms, insulating sleeves should be used where they pass through the floor. Uncovered brine mains accumulate masses of ice and cause lower temperature in spots. For this reason it is good practice to insulate such mains. Uncovered brine mains located near walls always damage insulation, and sometimes the structure.

Fig. 5. Three-Pipe Brine System.

In proportioning the size of brine mains it is well to weigh the initial cost against the cost of power required to overcome resistance to flow. The sum of the yearly fixed charges on the pipe and insulation, if any, the cost of the power required to circulate the brine through them, must be at a minimum. For brine mains of reasonable length the proper brine velocity can be taken at from 5 to 7 ft per sec.

The amount of cooling surface necessary for economical operation of the plant is based on space requirements. The minimum temperatures must be set first. Unless special apparatus is needed for quick freezing, the minimum temperatures required are usually:

Sharp freezers	−15 to −10 F
Carrying freezers	−10 to 0 F
Coolers	30 to 31 F

When the indirect or brine system of refrigeration is used, the corresponding brine temperatures usually carried range as follows:

Sharp and carrying freezer	−25 to − 5 F
Coolers	10 to 20 F

Design of Space Cooling Systems

Most of the cold storage spaces in this country are equipped with pipe coils through which the refrigerant or cold brine circulates to maintain the desired air temperature and humidity. These piping systems serve the purposes for which they were installed efficiently and effectively. Unit coolers or diffusers, originally designed for comfort cooling, are installed frequently with some modifications in newly equipped coolers and freezers.

The design of both systems are here discussed.

a. Piping Design. In proportioning the cooling surfaces for the various coolers and freezers it is important to keep in mind that ample cooling surfaces not alone mean high refrigerant temperatures and low operating costs, but also high humidity of the air in the rooms. This is a desirable conditioning for maintaining the quality of the perishables stored. At the same time the aim should be to have the operating costs plus all fixed charges a minimum. The following figures are based on the plant discussed in the last section above.

1. **Freezers**

Freezer space (Table 9), cu ft	2,126,000
Maximum average load (Table 4), tons	114
Number of refrigerated rooms	18
Average refrigerating load per room, tons	6.35

This refrigerating effect (6.35 tons) is required during the month of July when the house receives poultry, butter and other products to be frozen. Good practice requires that goods to be frozen be distributed over the various floors or rooms so as to prevent an unusual load in any one room. Since some of the rooms may be stored to capacity and several lots of goods may have to be stored in one room, the maximum average refrigerating effect per floor or room will not represent the actual refrigerating effect required. In general, the refrigeration needed per floor or room may be taken at a third more than the average, or in this case $6.35+2.12=8.47$ tons, and the cooling piping surface proportioned accordingly. The following calculation applies:

Temperature required in freezers, F	−10
Temperature rise in freezer brine, F	2.5
Initial brine temperature, F	−20
Mean temperature difference between rooms and brine, F	8.75

Heat transfer coefficient of piping system, 1.5 Btu per sq ft per hr per F

Length of 2-in. cooling piping required:

$$(8.47\times 12{,}000\times 1.608)/(1.5\times 8.75) = 12{,}400 \text{ ft}$$

These rooms contained 11,520 ft of 2-in. pipe, which together with return bends, headers and mains, make up approximately the required amount. The net volume per room is $2{,}126{,}000/18=118{,}100$ cu ft. There is thus required 1 ft of 2-in. pipe for each $118{,}100/12{,}400=9.5$ cu ft of freezer space.

This ratio will vary somewhat with the costs of piping and machinery. When they are low, a ratio of 1 ft of pipe for each 8 cu ft of freezer space should be used. Since the operating efficiency of direct expansion piping is not so high as that of the brine piping, the same amount of cooling piping

should be used in the former as in the latter case to obtain the same suction pressure on the system.

2. Coolers

Cooler space (Table 9), cu ft	3,674,000
Maximum average refrigerating load (Table 4), tons	96
Number of refrigerated rooms	27
Average refrigerating effect per room, tons	3.55

This average refrigerating effect is also required during the summer peak, but during this period the house does not receive the maximum quantity of perishables for cooler storage. This occurs generally in October when fruit, mostly apples, is received. For this reason the maximum refrigerating effect on which the cooling piping must be proportioned must be calculated from the average refrigerating effect required during that month. Average refrigerating effect required during the month of October may be taken as 82 tons or $82/27 = 3.0$ tons average per room. Fruit generates a large amount of heat when put in storage and before it is cooled down to room temperature. Therefore, it is necessary to increase the average refrigerating effect by 50 percent to obtain the maximum required at times. This maximum will therefore be $3.0 \times 1.5 = 4.5$ tons per room, which is greater than the July requirement.

Whereas in freezers the piping required is placed directly in the rooms, it has been found that to maintain the very uniform temperatures required in coolers, especially for the storage of eggs, the cold air circulating system is almost universally used. It is customary to provide separate air cooling bunkers for each floor of the cooler space so as to prevent odors generated in one room from being carried through the house. The following calculation is therefore based on this type of cooling system:

Temperature required in coolers, °F	31
Temperature rise in cooler brine, °F	2.5
Initial brine temperature, °F	15
Mean temperature difference between room and brine, °F	14.75
Heat transfer coefficient of piping system, per sq ft hr °F	2.5

Length of 1¼-in. air cooling piping required per room:

$(4.5 \times 12{,}000 \times 2.301)/(2.5 \times 14.75) = 3{,}370$ ft.

The average net cooler volume per room is: $3{,}674{,}000/27 = 136{,}000$ cu ft. There is thus required 1 ft of 1¼-in. pipe for $136{,}000/3370 = 40$ cu ft of net cooler space.

The cold air circulating system is designed to obtain a total air flow of from 6 to 10 times the net volume of the space cooled, per hour. The higher figure is now mainly used.

Since the heat leakage in freezer or cooler rooms under the roof or above warm spaces, or the ground, is greater than for other surfaces more favorably located, it is good practice to allow 15 percent more cooling surfaces for rooms under the roof and 10 percent more for rooms over warm spaces or over the ground. These percentages may vary somewhat with the design of the plant, but the proper amount of additional cooling surface required in rooms so located can be readily calculated from the maximum heat leakage that will take place through the roof or ground floor structure.

b. **Unit Coolers or Diffusers.** Diffusers may be of the dry pipe type, with plain or extended pipe surfaces, or of the spray type. If properly designed for the service they will refrigerate these spaces efficiently and carry the perishables without damage. Since forced air circulation is used in this design, it is most important that the cooling surfaces of the units be of sufficient extent so that a small logarithmic temperature difference can be maintained between the circulating air and the refrigerant. Experience has shown that the air of a forced air circulating system must be at a higher relative humidity than the air circulating by convection currents, or perishables will lose much moisture.

Removal of frost from the cooling surfaces of the dry pipe type diffusers is accomplished by spraying water over them, by hot refrigerant gas, by electric heating. These methods of defrosting, generally automatically controlled, find application for this type of diffuser whether placed in coolers or freezers.

To eliminate defrosting and maintain cooling efficiency, spray type diffusers are often chosen. For coolers maintained at temperatures near the freezing point, a common salt solution is sprayed over the

cooling surfaces. Salt must be added from time to time in the basin at the bottom of the unit so that the freezing point of the solution is kept below the temperature of the refrigerant. For spray type diffusers in carrying freezers maintained at 0 F or lower, a solution of one of the glycols can be used. These units are provided with a concentrator, heated either with steam or electric power, to keep the freezing point of the solution below the refrigerant temperature.

Freezing of Perishables

Public cold storage houses generally undertake to **freeze perishables.** In the ordinary freezer, the perishables are stacked with ample air space at temperatures of 0 to −10 F. After they are frozen, the goods are restacked for freezer storage. The disadvantages of this method of freezing are:

a. Too much space required
b. Extra labor required
c. Method is slow.

The trade demands that the perishables be frozen more quickly than is possible by convection air currents. Some houses have installed freezer tunnels.

For most freezing purposes it is sufficient to take a part of an existing freezer space and provide it with one or more nests of piping placed in enclosures, through which the air at a speed of from 1500 to 2500 ft per min is forced by fans. The average air temperature should be from −20 to −30 F. In order to get the minimum infiltration of water vapor into this quick freezer it should be placed in the existing carrying freezer space so that its four walls, the ceiling and floor are surrounded by freezers.

To reduce the labor of handling these goods the perishables are placed on skids on which they are frozen and then are moved by hand lift trucks to the carrying freezer where they are stacked for permanent storage. Pallets and fork trucks also serve to move and stack the frozen perishables in these cases.

High Side Requirements

There are a number of refrigerating **machine combinations** which may be used to handle the varying load, as well as high and low temperature brine requirements of a cold storage plant:

1. Two **compound compression** refrigerating machines with clearance pockets, one on low temperature brine work and the other on high temperature brine, is a desirable combination, a third unit of the same type being provided as a spare.
2. For smaller plants, one compound compression refrigerating machine with clearance pockets may be used. It is arranged with separate suction connections on head and crank ends of low pressure cylinder, the one end to take care of high brine work and the other end of low brine work; a second unit of the same capacity and arrangement is provided as a spare.
3. In such plants where the freezer work is relatively small, it is good practice to install a **booster compressor** with clearance pockets for discharging the low pressure suction vapor into the high pressure suction mains.

For large plants it is often desirable to limit the size of the machines and employ more units. When vertical single-acting machines with bypass capacity reducing devices are used, multiple refrigerating machine units must be installed to get the desired flexibility in handling the varying loads efficiently.

In large installations it is customary to introduce two-stage liquid cooling in the refrigerating cycle. Compound refrigerating machines are particularly well adapted for a simple arrangement of two-stage liquid cooling. In that case either the flash type or the closed type liquid cooler can be used to advantage.

If you searched this chapter for something which was not found in it, please let the editors know.

14. FOOD STORAGE CONDITIONS

THIS chapter presents information on the essential average storage requirements of most of the important perishable foods that enter the market on a commercial scale. The statements made are derived from scientific experimentation and from the best commercial practice at the present time.

The temperatures recommended are the optimum temperatures for long storage. For short storage, higher temperatures can often be used satisfactorily. Conversely, products having a higher optimum can usually be held at a lower temperature for a short time without injury. Exceptions are bananas, cranberries, cucumbers, melons, pumpkins and squash, white potatoes, sweet potatoes, and tomatoes. For these commodities, the temperatures recommended should be strictly adhered to.

The figures given for water content and freezing points are the result of actual laboratory determinations, but it should be realized that at best they can be only approximate because of the great variability in plant and animal tissues and the products thereof. The optimum storage temperature for many foods has been found to be just above their freezing point. Knowledge concerning these freezing points has therefore been useful to the cold storage industry in determining how the various commodities should be handled in storage. For example, Emperor and Tokay grapes were formerly stored at about 34 F. When it was found that the freezing point of these grapes was below 27 F, it became general practice to lower the storage temperature, thus prolonging the storage period about two months.

Figures on the water content of foods are useful to the refrigerating engineer as a basis for calculating specific heats and the latent heat of freezing.

The specific heat is ordinarily calculated by Siebel's formula

$$S=0.008a+0.20$$

(S signifies the specific heat of a substance containing a per cent of water; 0.20 is the value representing the specific heat of the solid constituents of the substance.)

Necessary additional information for some of the items listed is given in the text that follows **Table 1.** For further information on details of the storage of many of the commodities listed in the table, the reader should consult the publications listed at the end of this chapter.

Information in Table 1 on dairy and poultry products was furnished by H. G. F. Hamann, Production and Marketing Administration; on fish by J. M. Lemon, Division of Commercial Fisheries, Department of the Interior; on honey by George P. Walton, formerly Office of Distribution, War Food Administration; on maple syrup by C. F. Walton, Production and Marketing Administration, United States Depart-

DEAN H. ROSE, Co-author Chapter 14. Born 12/15/78 in Iona, Kansas. Educated at the Univ. of Kansas, AB, 1904; Univ. of Washington (St. Louis), AM, 1905; Univ. of Chicago, Ph.D., 1917. Formerly Botany Instructor, Kansas State Univ., 1907–12; Pathologist, Missouri Fruit Experiment Station, 1913–18; Pathologist, Fruit Disease Investigations, U. S. Dept. of Agriculture, 1918–27; Physiologist, U. S. Dept. of Agriculture, 1927 to 1928, Senior Physiologist, U. S. Dept. of Agriculture, 1928 to 1949; Retired, 1949.

Author of U.S.D.A. publications dealing with market and storage diseases of fruits and vegetables and the storage requirements of fresh fruits and vegetables; articles in *Refrig. Eng.* and "Food Industry."

Member of Sigma Xi; Amer. Soc. for Horticultural Science; Botanical Society of Washington.

R. C. WRIGHT, Co-author Chapter 14. Born 9/29/85 in London, Ohio. Educated at Ohio State University, BS, 1908; MS, 1912. Formerly Scientific Assistant, Soil Bacteriology, Bur. of Plant Industry, Soils and Agricultural Engineering, 1909–19; Physiologist, Fruit and Vegetable Storage Investigations, Bur. of Plant Industry, Soils and Agricultural Engineering, 1920 to date.

Author of USDA publications dealing with storage requirements of fruits and vegetables, especially storage of potatoes; articles in American Potato Journal, "Food Industry," and "Potato Chipper."

Member of Amer. Soc. for Horticultural Science; Fellow, Amer. Assn. for the Advancement of Science; Botanical Society of Washington.

At present Physiologist, Bur. of Plant Industry, Soils and Agricultural Engineering, U. S. Dept. of Agriculture, Beltsville, Md.

Table 1. Storage Requirements and Properties of Perishable Foods

Commodity	Storage temperature, F	Relative humidity, Percent	Approximate storage life	Water content, Percent	Average freezing point, F	Specific heat above freezing[5]	Specific heat below freezing[5]	Latent heat (calculated)[6] Btu
Apples	30 to 32	85 to 88	See Chapter 13	84.1	28.4	.87	.45	121
Apricots	31 to 32	80 to 85	1 to 2 wks	85.4	28.1	.88	.46	122
Artichokes								
Globe	31 to 32	90 to 95	1 to 2 wks	83.7	29.1	.87	.45	120
Jerusalem	31 to 32	90 to 95	2 to 5 mos	79.5	27.5	.83	.44	114
Asparagus	32	85 to 90	3 to 4 wks	93.0	29.8	.94	.48	134
Avocados	40 to 55[1]	85 to 90	—[1]	—[1]	27.2	—	—	—
Bananas	—[1]	—[1]	—[1]	74.8	—[1]	.80	.42	108
Beans								
Green or snap	32 to 40	85 to 90	2 to 4 wks	88.9	29.7	.91	.47	128
Lima	32 to 40	85 to 90	2 to 4 wks	66.5	30.1	.73	.40	94
Beets								
Bunch	32	85 to 90	10 to 14 days	—	—	—	—	—
Topped	32	95 to 98	1 to 3 mos	87.6	26.9	.90	.46	126
Blackberries	31 to 32	80 to 98	7 to 10 days	85.3	28.9	.88	.46	122
Broccoli, sprouting	32 to 35	90 to 95	7 to 10 days	89.9	29.2	.92	.47	130
Brussels sprouts	32 to 35	90 to 95	3 to 4 wks	84.9	—	.88	.46	122
Butter	—	—	—	—	—	.33	.25	23
Cabbage	32	90 to 95	3 to 4 mos	92.4	31.2	.94	.47	132
Carrots								
Bunch	32	85 to 90	10 to 14 days	—	—	—	—	—
Topped	32	95 to 98	4 to 5 mos	88.2	29.6	.90	.46	126
Cauliflower	32	85 to 90	2 to 3 wks	91.7	30.1	.93	.47	132
Celeriac	32	95 to 98	3 to 4 mos	88.3	—	.91	.46	126
Celery	31 to 32	90 to 95	2 to 4 mos	93.7	29.7	.95	.48	135
Cheese	Approx. 34	65 to 70	—[1]	37 to 38	Approx. 28.0	.50	.31	54
Cherries	31 to 32	80 to 85	10 to 14 days	83.0	—[2]	.87	.45	120
Chocolate candies	68 to 70	50 to 55	6 to 10 mos	—	—	—	—	—
Corn, sweet	31 to 32	85 to 90	—[1]	73.9	28.9	.79	.42	106
Cranberries	36 to 40	85 to 90	1 to 3 mos	87.4	27.3	.90	.46	124
Cucumbers	45 to 50	80 to 85	10 to 14 days	96.1	30.5	.97	.49	137
Currants	32	80 to 85	10 to 14 days	84.7	—	.88	.45	120
Dairy products								
Cheese	35	—	See Chap. 23, Table 8	—	—	—	—	—
Butter	45	—	2 mos	—	—	—	—	—
	−10	—	1 yr	—	—	—	—	—

Cream (sweetened)	−15	—	several months	—	—	—	—	—
Ice cream	−15	—	several months	—	—	—	—	—
Skim milk								
Dried	40	—	several months	—	—	—	—	—
Unsweetened	−15	—	short time	—	—	—	—	—
Sweetened	35	—	several months	—	—	—	—	—
Dates	—[1]	—[1]	—[1]	20.0	−4.1	.36	.26	29
Dewberries	31 to 32	80 to 85	7 to 10 days	—	29.2	—	—	—
Dried fruits	—[1]	—[1]	9 to 12 mos	—	—	.30 to .32	—	17 to 21
Eggplant	45 to 50	85 to 90	7 to 10 days	92.7	30.4	.94	.48	132
Eggs								
Shell	29 to 31	85 to 90	9 mos	67.0	Approx. 28.0	.74	.40	96
Shell, farm cooler	40 to 55	75	—	67.0	Approx. 28.0	.74	.40	96
Frozen	Frozen, −20	—	—[1]	73.0	Approx. 28.0	—	.42	104
	Hold, 0	—	—[1]	73.0				
Dried, whole	35	Low as possible	6 mos	6.0	—	.25	.21	9
Dried, yolk	35	Low as possible	6 mos	—	—	—	—	—
Dried spray albumen	35	Low as possible	6 mos	Up to 6.0	—	.25	—	9
Fermented albumen	Room temp.	Low as possible	—	3 to 15	—	.22 to .32	—	4 to 21
Endive (escarole)	32	90 to 95	2 to 3 wks	93.3	30.9	.94	.48	132
Figs								
Dried	40 to 45	65 to 75	9 to 12 mos	24.0	—	.39	.27	34
Fresh	28 to 32	65 to 75	5 to 7 days	78.0	27.1[3]	.82	.43	112
Fish								
Fresh	33 to 40	90 to 95	5 to 20 days	—	—	—	—	—
Frozen	0 to 10	90 to 95	8 to 10 mos	—	—	—	—	—
Smoked	40 to 50	50 to 60	6 to 8 mos	—	—	—	—	—
Brine salted	40 to 50	90 to 95	10 to 12 mos	—	—	—	—	—
Mild cured	28 to 35	75 to 90	4 to 8 mos	—	—	—	—	—
Frozen-pack fruits	−10 to 0	—	6 to 12 mos	—	—	—	—	—
Frozen-pack vegetables	−10 to 0	—	6 to 12 mos	—	—	—	—	—
Garlic, dry	32	70 to 75	6 to 8 mos	74.2	25.4	.79	.42	106
Gooseberries	31 to 32	80 to 85	3 to 4 wks	88.3	28.9	.90	.46	126
Grapefruit	—[1]	85 to 90	6 to 8 wks	88.8	28.4	.91	.46	126
Grapes								
American type	31 to 32	80 to 85	3 to 8 wks	81.9	27.5	.86	.44	116
European type	30 to 31	80 to 85	3 to 6 mos	81.6	24.9	.86	.44	116
Honey	—[1]	—[1]	—[1]	—[1]	—	—	—	—
Horseradish	32	95 to 98	10 to 12 mos	73.4	26.4	.78	.42	104
Kohlrabi	32	95 to 98	2 to 4 wks	90.1	30.0	.92	.47	128
Lard (without antioxidant)	32 to 33	90 to 95	4 to 8 mos	—	—	—	—	—
"	0	90 to 95	12 to 14 mos	—	—	—	—	—

Table 1. (Continued)

Commodity	Storage temperature, F	Relative humidity, Percent	Approximate storage life	Water content, Percent	Average freezing point, F	Specific heat above freezing[5]	Specific heat below freezing[5]	Latent heat (calculated)[6] Btu
Leeks, green	32	85 to 90	1 to 3 mos	88.2	29.2	.90	.46	126
Lemons	55 to 58	85 to 90	1 to 4 mos	89.3	28.1	.92	.46	127
Lettuce	32	90 to 95	2 to 3 wks	94.8	31.2	.96	.48	136
Limes	45 to 48	85 to 90	6 to 8 wks	86.0	29.3	.89	.46	122
Logan blackberries	31 to 32	80 to 85	7 to 10 days	82.9	29.5	.86	.45	118
Malt syrup	—[1]	—[1]	—[1]	—	—	—	—	—
Maple syrup	—[1]	—[1]	—[1]	—	—	—	—	—
Meat								
Bacon								
Fresh	−10 to 0	90 to 95	4 to 6 mos	—	—	—	—	—
Smoked	60 to 65	85	4 to 6 mos	13 to 29	—	.30 to .43	.24 to .29	18 to 41
Beef								
Fresh	32 to 34	88 to 92	1 to 6 wks	62 to 77	28 to 29	.70 to .84	.38 to .43	89 to 110
Frozen	−10 to 0	90 to 95	9 to 12 mos	—	—	—	—	—
Fat backs	38 to 40	85 to 90	0 to 3 mos	—	—	—	—	—
Hams and shoulders								
Fresh	32 to 34	85 to 90	7 to 12 days	47 to 54	28 to 29	.58 to .63	.34 to .36	67 to 77
Frozen	−10 to 0	90 to 95	6 to 8 mos	—	—	—	—	—
Cured	60 to 65	75 to 80	0 to 3 yrs	40 to 45	—	.52 to .56	.32 to .33	57 to 64
Lamb								
Fresh	32 to 34	85 to 90	5 to 12 days	60 to 70	28 to 29	.68 to .76	.38 to .51	86 to 100
Frozen	−10 to 0	90 to 95	8 to 10 mos	—	—	—	—	—
Pork								
Fresh	32 to 34	85 to 90	3 to 7 days	35 to 42	28 to 29	.48 to .54	.30 to .32	50 to 60
Frozen	−10 to 0	90 to 95	4 to 8 mos	—	—	—	—	—
Sausage								
Smoked	40 to 45	85 to 90	—	—	—	—	—	—
Casings	40 to 45	85 to 90	—	—	—	—	—	—
Veal	32 to 34	90 to 95	5 to 10 days	70 to 80	28 to 29	.76 to .84	.42 to .51	100 to 114
Melons								
Casaba and Persian	36 to 40	75 to 85	4 to 6 wks	—	—	—	—	—
Honey Dew and Honey Ball	36 to 38	75 to 85	2 to 4 wks	92.6	29.0	.94	.48	132
Muskmelons	32 to 34	75 to 78	7 to 10 days	92.7	29.0	.94	.48	132
Watermelons	36 to 40	75 to 85	2 to 3 wks	92.1	29.2	.97	.48	132
Mushrooms	32 to 35	80 to 85	2 to 3 days	91.1	30.2	.93	.47	130
Nuts, dried	32 to 50[1]	65 to 75	8 to 12 mos	3 to 6	—[1]	.22 to .25	.21 to .22	4 to 8
Oil (vegetable salad)	55	—	6 mos	—	—	—	—	—
	35	—	1 yr	—	—	—	—	—
Oleomargarine	55	60 to 70	6 mos	—	—	—	—	—
	35	60 to 70	1 year	—	—	—	—	—
Olives, fresh	45 to 50	85 to 90	4 to 6 wks	75.2	28.5	.80	.42	108
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.1	.90	.46	124

Oranges	32 to 34	85 to 90	8 to 10 wks	87.2	28.0	.90	.40	124
Parsnips	32	90 to 95	2 to 4 mos	78.6	28.9	.84	.46	112
Peaches	31 to 32	80 to 85	2 to 4 wks	86.9	29.4	.90	.46	124
Pears	29 to 31	85 to 90	—[1]	83.5 (Bartlett)	—[1]	.86	.45	118
Peas, green	32	85 to 90	1 to 2 wks	74.3	30.0	.79	.42	106
Peppers								
Sweet	32	85 to 90	4 to 6 wks	92.4	30.1	.94	.47	132
Chili (dry)	32 to 50	70 to 75	6 to 9 mos	—	—	—	—	—
Persimmons	31 to 32	85 to 90	2 to 3 wks	78.2	28.3	.84	.43	112
Pineapples								
Mature green	50 to 60	85 to 90	3 to 4 wks	—	29.1	—	—	—
Ripe	40 to 45	85 to 90	2 to 4 wks	85.3	29.9	.88	.45	122
Plums, including fresh prunes	31 to 32	80 to 85	3 to 8 wks[1]	85.7	28.0	.88	.45	123
Potatoes	38 to 50[1]	85 to 90	—[1]	77.8	28.9	.82	.43	111
Poultry								
Fresh	32	—	1 wk.	—	—	—	—	—
Frozen, New York dressed	−20	—	—[1]	—	—	—	—	—
Frozen, eviscerated	−20	—	—[1]	—	—	—	—	—
Pumpkins and squashes	50 to 55	70 to 75	2 to 6 mos	90.5	—[4]	.92	.47	130
Quinces	31 to 32	80 to 85	2 to 3 mos	85.3	28.1	.88	.45	122
Radishes, winter	32	92 to 98	2 to 4 mos	93.6	—	.95	.48	134
Rabbits								
Fresh	32 to 34	90 to 95	1 to 5 days	—	—	—	—	—
Frozen	−10 to 0	90 to 95	0 to 6 mos	—	—	—	—	—
Raspberries								
Black	31 to 32	80 to 85	7 to 10 days	80.7	29.9	.84	.44	122
Red	31 to 32	80 to 85	7 to 10 days	83.4	30.4	.86	.45	122
Rhubarb	32	90 to 95	2 to 3 wks	94.9	28.4	.96	.48	134
Rutabagas	32	95 to 98	2 to 4 mos	89.1	29.5	.91	.47	127
Salsify	32	95 to 98	2 to 4 mos	79.1	28.4	.83	.44	113
Spinach	32	90 to 95	10 to 14 days	92.7	30.3	.94	.48	132
Strawberries	31 to 32	80 to 85	7 to 10 days	90.0	29.9	.92	.47	129
Sweetpotatoes	55 to 60	75 to 80	4 to 6 mos	68.5	28.5	.75	.40	97
Tomatoes								
Mature green	55 to 70[1]	85 to 90[1]	3 to 5 wks[1]	94.7	30.4	.95	.48	134
Ripe	40 to 50[1]	85 to 90[1]	7 to 10 days[1]	94.1	30.4	.95	.48	134
Turnips	32	95 to 98	4 to 5 mos	90.9	30.5	.93	.47	130
Yeast	31 to 32	—	—	—	—	—	—	—

[1] See text.
[2] Eastern Sour, 28.0; Eastern Sweet, 24.7; California Sweet, 24.2.
[3] Mission variety.
[4] Pumpkins, 30.2; winter squash, 29.3.
[5] Calculated by Siebel's formula, see p. 163. For values above freezing point $S = 0.008a + 0.20$. For values below freezing point $S = 0.003a + 0.20$. (Work on the Calorimetric determination of specific heats is now in progress at the University of Texas but values thus obtained are available for only a few products and therefore are not included in this tabulation.)
[6] Values for latent heat (latent heat of fusion) in Btu per pound, calculated by multiplying the percentage of water content by the latent heat of fusion of water, 143.4 Btu.

ment of Agriculture; and on meat and meat products by R. L. Hiner, Bureau of Animal Industry, United States Department of Agriculture. Figures on the water content of fruits and vegetables and of certain other items in the table are taken from the circular by Chatfield and Adams. (See bibliography.) Figures for the freezing points of fruits and vegetables are from the circular by Wright. (See bibliography.)

It will be noted that the values for specific heat above freezing and below freezing and for latent heat given in Table 5, Chapter 12 and Table 7, Chapter 19 of the 1949 Basic Volume of the ASRE Data Book do not agree exactly, and some values do not agree with the data given in Table 1 of this chapter. The composition of foods varies to some extent, depending upon various localities, water content, where grown and other factors. It is also possible that in tables compiled by different authors, slightly different formulas have been used in making calculations to determine both specific and latent heat. For this reason, slight variations in data compiled by various sources can be expected and should be no cause for alarm. The values given in any of these tables can safely be used for refrigeration load calculations. When in doubt, it is suggested that the higher values be used. For exacting work, the specific heat and other values should be determined for the specific sample in question if the work justifies such close tolerances.

Avocados

Investigations in California on the storage of avocados have shown that the **best temperature** for all varieties grown there except the Fuerte, is about **40 F.** The Fuerte discolors internally at this temperature but holds up well at 45 F. At temperatures below 40 F all the varieties investigated are likely to become discolored internally and do not soften when removed to a higher temperature.

When properly stored, the Dickinson, Royal, Taft, and Queen varieties of avocado are said to hold up well for about two months, the Spinks, Sharpless, and Challenge for five to six weeks, and the Ray, Fuerte, and Kist for about four weeks. Most of these varieties are of the Guatemalan race.

No general recommendations can be made concerning the storage of varieties of avocados grown in Florida, Central America, or the West Indies, because of the wide variation among them in susceptibility to injury by low temperatures. Many varieties of the West Indian race are injured by exposure to a temperature of 50 to 53 F for 15 days, whereas others (Pollock, Trapp) remain in good condition for three weeks when held at 42 F. Some of the varieties that are least affected by cold (Lulu, Taylor) can safely be held at 37 to 42 F for four weeks.

Water content, per cent: Fuerte, 65.4; Mexican type, 66.7; Guatemalan type, 74.1; West Indian type, 82.2.

Bananas

The **lowest temperature** at which green bananas can safely be held in order to delay ripening is about **56 F;** below this, bananas suffer an injury known as chilling, which prevents their ripening properly when later removed to a suitable temperature, and sometimes results in discolored spots on the skin. The best holding temperature for ripe bananas is generally considered to be 56 F, at which temperature they should keep satisfactorily for a week to ten days.

Green fresh bananas have a **freezing point** of 30.2 F for the flesh and 29.8 F for the peel. In the case of ripe bananas the figures are 26.0 and 29.4.

Corn

If sweet corn is to be stored it should be held at **31 to 32 F** with a **relative humidity of 90 to 95 percent.** This product rapidly loses its sugar content and therefore much of its flavor soon after picking if not quickly cooled. Even at 32 F much sugar is lost, but corn can be kept in salable condition at this temperature one to four weeks, depending on the condition when stored.

Dates

Dates **absorb moisture** and **odors** readily from the air. The rate of absorption is

much less at temperatures below 32 F than at those above 32 F. Deterioration caused by humidity above 75 percent is slow at storage temperatures below 28 F. The dates of commerce are of three grades with respect to storage life—dry, cured, and non-cured. The cured and non-cured grades are perishable. A **temperature as low as 0 F** has no deleterious effect upon dates, but is actually **beneficial** to them.

Dates are of two different types, and fruits of each type are likely to be either dry, cured, or non-cured. The **cane-sugar** type is usually firm, light-colored, and comparatively dry, whereas the **invert-sugar** type is usually softer, darker colored, and inclined to be slightly sticky or syrupy.

Deglet Noor, the most important variety grown in this country, is of the cane-sugar type. Dates of this variety, cured grade, keep well until March at 28 to 32 F. and for a year at 24 to 26 F or lower, whereas the non-cured grade requires 18 F or lower for storage until March, and 0 to 10 F to hold for a year. In Deglet Noor dates that have become overripe or have been held under unfavorable storage conditions, the cane-sugar is inverted and the dates become soft, syrupy, and darker in color. Such dates are commonly graded as "dark soft." If they can be dried somewhat they can be stored at 28 to 32 F until Christmas without becoming objectionably dark and syrupy, although a temperature of 0 to 10 F will be needed if they are to be stored until March. If such dates are not cured, a temperature of 0 to 10 F is necessary for even short-time storage.

Invert-sugar type dates are subject to sugar spotting at ordinary storage temperatures when the moisture content is within the range of about 22 to 33 percent. If a moisture content within this range is desired, control of sugar spotting can be attained by lowering the storage temperature; the temperature required depends upon the length of time it is desired to store the dates. They can be kept free from spotting for one to two years at −10 F. If control of spotting is to be attained by maintaining a moisture content above 33 percent, it will still be necessary to lower the temperature to prevent too much darkening.

Halawy (Halawi), Khadrawy (Khadrawi), Zahidi, and Saidy dates are all of the invert-sugar type, and the cured grades can be kept until Christmas at 28 to 32 F without forming sugar spots but require a temperature of 18 F or lower if stored until March. Non-cured grades of these varieties require 0 to 10 F for even short storage. After Christmas it is well to shift all dates of invert-sugar type remaining in storage to freezers at 0 to −10 F, the temperature used depending on the length of prospective storage.

Dried Fruits

For the preservation of natural color in storage, **cut dried fruits** and **dried berries** that are not subject to sugaring are held at 26 F with no humidity control, or at 32 F with a relative humidity of 70 to 75 percent.

Dried **figs and prunes** are best stored at 40 to 45 F. The relative humidity should not be over 70 to 75 percent, to prevent excessive absorption of moisture. Dried **apples, apricots,** and **peaches** keep best at 26 to 32 F. **Raisins** should be stored at 40 to 45 F and require a relative humidity of 50 to 60 percent to keep them from absorbing moisture. The holding of dried fruit in high humidity at temperatures above 32 F is likely to result in mold. A relative humidity of 55 percent effectively controls mold growth as well as the crystallizing out of sugar. The dried fruits mentioned can be kept in marketable condition for 9 to 12 months at the temperatures and humidities specified.

Dried fruit can be tightly stacked, without stripping, in large solid blocks in storage rooms without injurious effect, and this method of handling the packages minimizes the absorption of moisture from the storage-room air. When non-ventilated packages, such as those used for dried fruit and dates, are removed from cold rooms, the sweating that results occurs mostly on the outside of the package. The moisture can be prevented from penetrating into the fruit by using moisture-proof containers or by allowing the packages to warm up before they are opened.

Grapefruit

For short-time storage, grapefruit can be held satisfactorily at a temperature of 32 F. For longer periods the temperature to be used will depend on the character of the fruit and the troubles most likely to be encountered. For fruit grown in sections where stem end rot is prevalent, this disease is likely to be the determining factor; it will generally be advisable to use a comparatively low temperature range (32 to 34 F). On the other hand if the fruit is grown in regions where stem end rot is not prevalent, the limiting factors are likely to be storage pitting and watery breakdown, which develop most seriously at temperatures of 40 F or lower. For fruit from these regions a temperature of 45 to 55 F is satisfactory, and the more rapid development of undesirable high color and the increase in blue mold and green mold rots at the higher temperatures have not been found so objectionable on such fruits as the pitting that results from storage at lower temperatures.

Sound fruit that is not overmature or likely to suffer from stem end rot can usually be held for six weeks without serious spoilage at the higher temperature ranges mentioned above, and this storage period can sometimes be doubled with satisfactory results. Weak or overmature fruit requires close watching from the time it is removed from the tree, regardless of storage conditions.

The percentage of stem end rot in Florida and Texas grapefruit will be greatly reduced if the fruit is properly treated with borax or sodium metaborate, pulled from the tree instead of being clipped, and precooled before being shipped. The disbuttoning that may occur during handling and packing is also effective in reducing loss from stem end rot. As compared with stem end rot, blue mold and green mold rots are relatively less important on Florida grapefruit in storage. Stem end rot is not known to occur on California and Arizona fruit. (See also Chap. 16.)

Honey

Both liquid and comb honey can be held satisfactorily in common, or dry storage for about a year. After longer storage honey is likely gradually to turn dark and deteriorate in flavor. Cold storage temperatures (40 F or lower) are not necessary or desirable because they favor crystallization (granulation) of some of the sugar. The sugar can be re-dissolved by warming the honey to 120 to 140 F with stirring. It should be remembered that when crystallization takes place the relative water content of the liquid portion becomes higher than that of the original honey and may become high enough to favor fermentation, at subsequent common-storage temperatures. The optimum temperature for the fermentation of honey is 60 F and the dextrose (sugar) crystallization proceeds more rapidly at about 57 F than at other temperatures.

Although 21 percent of moisture in honey (or in the liquid phase of granulated honey) has been generally considered to be the critical dilution at which fermentation will occur, Canadian investigators have reported that when the sugar-tolerant yeasts commonly found in honey are present in large numbers, fermentation may occur at greater concentrations.

A dry atmosphere is particularly important for comb honey because in a damp place it can absorb moisture through the wax, become diluted, and then ferment.

Maple Syrup

Maple syrup, if properly packed at the pasteurizing temperature in clean containers that are promptly closed air-tight, will keep indefinitely in common (unrefrigerated) storage. Cold storage is not necessary. However, once a container (bottle, can, or drum) has been opened, so that the syrup is exposed to the air, it may mold, even when kept in a household refrigerator or cold storage room. If kept in a warm place it may ferment.

For packing in small containers the syrup should be at 180 F, whereas 140 F is high enough for 50-gal drums because the larger quantity remains at a pasteurizing temperature for a longer time.

Malt Syrup

In commercial practice malt syrup is not usually refrigerated, because it is too difficult to handle at low temperatures. The temperatures most used range from 60 to

70 F. Most syrups are fairly stable at these temperatures and can be satisfactorily stored for periods up to two years.

Syrups with densities of 42° Be. or greater present no problem in decomposition by growth of microorganisms. Thinner syrups are likely to decompose unless kept under refrigeration.

Nuts

Nuts are often stored from one production season to the next. They are usually stored at **32 to 35 F** to prevent development of rancidity and decay and also insect damage. Where the latter only is feared, a temperature of 50 F is low enough. Pecan and Brazil nuts are the kinds most subject to deterioration and both should be stored at 32 to 35 F. Walnuts, almonds and filberts deteriorate more slowly and usually a temperature of 45 to 50 F will be satisfactory for them. Shelled nuts, unless sealed in vacuum, will not keep so long as unshelled ones.

Store nuts in separate rooms or only with products such as dried eggs, dried milk and canned goods without strong odors. Keep away from dried apricots, smoked meats, apples and onions especially.

Freezing points: Persian (English) walnuts, 20.0 F; pecans, 19.6 F; chestnuts, 23.8 F.

Oranges

Careful handling during picking and packing is highly important in reducing decay of oranges. The **best storage temperature is 34 to 38 F;** they do not store well for longer than one to two months. If stored too long, oranges become pitted anywhere on the surface or develop large brown, slightly sunken spots at the stem end. Fruit in storage should be inspected frequently. When fruit is properly handled through the coloring or degreening process and placed in cold storage at once, there is little or no increase in decay within a reasonable time for marketing and consuming, or if the fruit is held continuously in storage at 34 to 38 F for not more than about two months. (See also Chap. 16.)

Pears

Bartlett pears for storage should not be removed from the tree until the ground color begins to lighten and the lenticels (dots) have corked over. If picked before reaching that stage they tend to wilt, scald, and break down in storage, but they also tend to break down in storage if picked too ripe. The most desirable **storage temperature for pears is 29 to 31 F,** with a relative humidity of 85 to 90 percent. After removal from storage all pears attain best quality if held at a temperature of about 65 F for ripening.

The commonest and most serious decay of pears in storage, **gray mold rot,** can be controlled by the use of paper wrappers impregnated with a copper compound. Bartlett and Anjou pears exposed for a long time to temperatures just below their freezing point have a glassy, water-soaked appearance on the outside and a similar appearance when cut. Such fruits are rather resistant to decay and do not undergo internal breakdown from overmaturity.

Freezing points: Winter Nelis, 27.2 F; Anjou, 26.9 F; Bartlett, 28.5 F. (See also Chap. 15.)

Plums and Prunes

Plums and prunes (fresh) are not stored extensively and **not adapted to long storage.** Abundance, Wild Goose, and varieties of the damson type store better than the softer-fleshed plums, such as Santa Rosa, Beauty, Wickson, and Duarte. If held longer than about two weeks, even at 32 F all varieties become too ripe for commercial handling and lose somewhat in flavor. Italian prunes, if held longer than about three weeks, are likely to develop internal breakdown as well as abnormal odor and flavor. Too much confidence should not be placed in the appearance and condition of the fruit while it is in storage, as more deterioration, decay, shriveling, and internal browning may take place within three days after removal from storage than during the whole storage period.

Potatoes

The **best all-round storage temperature** for potatoes is probably **40 F,** with a relative humidity of 85 to 90 percent to prevent undue shrinkage. At this temperature sprouting is delayed three to five months after harvest, and then growth is very slow.

Table stock stored at temperatures be-

low this will be undesirably sweet. Recent investigations have shown that potatoes stored at 50 to 60 F have the best flavor, texture, and color when cooked, although those stored at 40 F should prove satisfactory for most culinary uses. For chip manufacture potatoes stored at 60 F make the best product, and those from temperatures below 50 F are very likely to be unusable. Sprouting will occur more quickly at these higher temperatures but can be checked by lowering the temperature to 40 F, or by storing at 40 F and removing to 60 F two to three weeks before the stock is needed. Potatoes that are undesirably sweet for table use will lose much of their **sugar** if moved to 60 F for two to three weeks, but may not fully recover their original condition or culinary quality.

Seed stock is best stored at about 40 F in the beginning. This will be suitable for early planting. Stock desired for late planting should be moved to about 38 F after three to five months. At 36 to 38 F potatoes will remain dormant indefinitely. Potatoes should not be stored in the same room with fruits, nuts, eggs, or dairy products because of the objectionable flavor they will impart.

Tomatoes

Tomatoes, either mature green or ripe, should **not be stored** for **long periods** at temperatures **below 50 F.** Hard ripe fruit can be kept from a week to 10 days at 50 F, while unripened tomatoes can best be kept at 55 F. They will ripen very slowly at this temperature but will remain in good salable condition for two to six weeks. For rapid ripening 70 F is the optimum. The relative humidity of tomato storage or ripening rooms should be 85 to 90 percent. Storage temperatures below those given tend to produce physiological breakdown, although as long as four to eight days at 32 F usually will not prevent subsequent ripening. Claims are often mistakenly made for chilling injury when the objectionable condition is due to immaturity of the tomatoes when harvested.

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If you searched this chapter for something which was not found in it, **please let the editors know.**

15. APPLES, PEARS, AND GRAPES

APPLES, pears, and grapes are all important storage commodities, apples leading all other fruits with approximately 31 million bushels normally in cold storage by December. About 4 million bushels of pears are stored annually and 5 million packages (28-lb lugs) of grapes. The combined storage of these fruits amounts to approximately 50,000 carloads. The important **storage varieties** of **apples** are Delicious, Winesap, Rome Beauty, Yellow Newtown, and Jonathan in the Pacific Northwest; Yellow Newtown in California; McIntosh, Baldwin, and Rhode Island Greening in the northeastern states; and York Imperial, Stayman Winesap, Delicious, Rome Beauty and Winesap in the central Atlantic States.[17] The important **storage varieties** of **pears** are Bartlett, stored in large quantities for cannery use, Anjou, Bosc, Hardy, Winter Nelis, Comice, and Kieffer, all but the last being grown chiefly in the Pacific Coast states. Most of the **grapes** that are **stored** are of the *vinifera* type, grown in California, of which the Emperor is the principal variety stored, although Sultanina (Thompson Seedless), Ohanez (Almeria), Flame Tokay, and Alphonse Lavallee (Ribier) are also stored to some extent.

FRANK W. ALLEN, Co-author Chapter 15. Born 7/18/87, in Columbia, Missouri. Educated at Univ. of Missouri, BSA, 1910; Iowa State College, MS, 1913. Formerly Instructor in Horticulture, Iowa State College, 1910–13; Washington State College, 1913–14; Assistant Horticulturist, Washington State College, 1914–17; Bureau of Markets, USDA Fruit Transportation and Storage Investigations, Yakima, Wash., 1917–20; Assistant Professor of Pomology, Univ. of California, 1920–25; Assistant Pomologist, 1925–29; Associate Pomologist, 1929–38; Assoc. Professor and Assoc. Pomologist, 1938–43; Associate Professor and Pomologist, 1943–46; Professor and Pomologist, 1946 to date.

Author of numerous technical and semi-technical papers and popular reports on fruit production and problems relating to handling, shipping and storage practices issued from the California Agricultural Experiment Station, or jointly from the Calif. Agricultural Experiment Station and USDA. Co-author Chapter 13, 1946 Applications Volume, ASRE Data Books; numerous articles in trade and technical journals on handling, transportation, and storage of fruit.

Member, Amer. Soc. for Horticultural Science; Natl. Assn. of Refrigerated Warehouses (Honorary); Research Committee, Pacific States Cold Storage Warehousemen's Assn., 1938–40; Biology and Food Chemistry Committee, Institute International du Froid, Paris, 1938–40; Scientific Advisory Council, The Refrigeration Research Foundation, 1944 to date.

Appointed 1936 by the Governor General of South Africa to membership in International committee of three (one each from England, U. S., and Germany) to study conditions at Capetown, advise the South African Government on precooling, storage and shipping practice of deciduous fruits from that port.

At present Professor of Pomology, Univ. of California and Pomologist in the Agricultural Experiment Station.

W. T. PENTZER, Associate Editor Section II and Co-author, Chapter 15.

APPLES

Previous to harvest, the fruit receives a continuous supply of food materials from the tree. A part of these is used for growth and a part is stored in the tissues. They accumulate at different rates until the fruit is mature. Both before and after harvest the fruit constantly takes in oxygen and gives off carbon dioxide, a **respiration process** basically the same as that of animals. The apple should therefore be considered as a **living organism,** with life processes continually taking place in its tissues. When it is removed from the tree, it is cut off from its source of food supply, but the process of respiration continues. The apple then lives by the gradual utilization of a part of its stored food. While this supply of stored food is not ordinarily used up, the starch, sugar, and acid constituents of the apples gradually change in storage until the life processes cease and the apple becomes "dead" and no longer edible. This usually occurs when the pectin in the cell walls dissolves out and the fruit becomes soft and mealy. The most effective and practical method of arresting these undesirable changes in the fruit after harvest is to subject it to a temperature as low as possible without freezing it.

The **function of cold storage** in holding fruit in its fresh state is not to stop the life processes but only to reduce the rate at which they take place. Throughout the

normal storage period, therefore, storage warehousemen are concerned with a living product requiring consideration of temperatures, humidity, composition of the atmosphere, and other factors which influence the ripening processes, retention of dessert quality and have a bearing upon important storage diseases.

Temperature and storage conditions. Where uniform temperatures can be held, 30–31 F is recommended for **longest holding** of most varieties. In general, apples will keep approximately 25 percent longer at 30 F than at 32 F. Scald and decay are likewise less prevalent at the lower temperature.[18] The freezing temperature of different varieties of mature fall and winter apples ranges from 27.8 to 29.4 F with an average of 28.5 F.[36] Storage temperatures of 30 to 32 F thus can be employed without **danger of freezing** the fruit.

The storage life of apples, however, is not always limited by fungous rots or by normal "old age." Some varieties, especially when grown under certain climatic conditions, are subject to one or more **physiological diseases** induced by storage at too low temperatures.

McIntosh, Rhode Island Greening, Twenty Ounce, and Baldwin apples grown in New York and New England sometimes develop **brown core** when stored below 36 F.[29] A form of the same low temperature trouble, known as **internal browning**, develops in many of the Yellow Newtown apples grown in the Pajaro Valley of California. The trouble does not develop at 40 F, but on account of their more rapid ripening at this temperature a compromise temperature of 36–37 F has been adopted for commercial storage of these apples.

Grimes Golden, Golden Delicious, Jonathan, Winesap, Winter Banana, and some other varieties are subject to **soft scald** and **soggy breakdown** at temperatures below 35 F.[25,26] When harvested at proper maturity and stored promptly, these varieties can be successfully held at 30–31 F. However, since these apples can seldom be placed in storage soon enough under commercial conditions and are less susceptible to these disorders if held at 36 F, this is the temperature sometimes used for them, especially where long holding is not essential. It is seldom possible for warehousemen to offer different storage temperatures for different varieties or lots. Therefore, it is usually more feasible for producers of apples requiring special treatment of the kind indicated to provide it in storages which they can operate and control than to depend upon a public warehouseman.

Both before and after harvesting, apples are continually losing moisture, largely through the lenticels or pores in the skin. After the source of moisture supply is cut off by harvesting, the apples will **wilt unless they are kept in a moist atmosphere.** At 30–32 F atmospheres should be kept at 88–90 percent rh to keep the apples in best condition; at 36 F the rh should be 90 percent or more. When stored in an atmosphere of only 75–80 percent rh, some varieties lose 3 to 5 percent in weight, shriveling becomes apparent, and the flesh loses its normal crispness.

An atmosphere close to saturation, 95 percent or higher, has been found necessary to prevent moisture loss entirely from apples and pears. Humidity as high as this, however, is difficult to maintain at or below 32 F and also favors **mold growth** on the fruit, packages, and walls of the room. Surface molds can be controlled by introducing **ozone** into the rooms, by fumigating with **sulfur dioxide** when they are empty, or by spraying the interior surfaces with a **chlorine** solution or other fungicides. Frequent **painting** with a suitable cold storage paint is also recommended. The recommendation of 88–90 percent rh at 30–31 F is, therefore, a compromise between that which entirely prevents moisture loss, and that at which appreciable shriveling will occur.

Because of the difficulty in maintaining high humidities, especially at the beginning of the storage period, frequently little or no attention is given to increasing the moisture content of the air in storage rooms above that at which it eventually levels off after the rooms are filled with fruit. In many instances the filling of the rooms may require a period of several weeks. In other instances where large

rooms are filled within one or two days, air and fruit temperatures may remain relatively high for a considerable period, thus increasing the need for high humidities.

Under most conditions, apples are packed in comparatively dry boxes with dry pads and wrapped in dry paper. The floor, ceiling, and walls of the room are also relatively dry at the time. Therefore, unless a high humidity is maintained in the air, the **"leveling off"** process will be at the expense of the fruit. Experimental results[22] have shown that dry boxes and packing material alone may absorb one pound or more of moisture per package. To reduce this loss of moisture from the fruit, it will help if **dry packages are moistened before use.** Moisture may also be added to the room, both before and after filling with fruit, but to maintain high humidity with a minimum deposition of moisture on the coils or dilution of a brine spray, there should be a sufficient area of cooling surface to keep the **temperature difference as small as possible** between the coils or spray and the temperature in the room.

Although **ventilation** of cold storage rooms will prevent accumulation of volatile products given off from the fruit and may be of advantage with varieties of apples susceptible to scald, introduction of **outside air** to the storage room is **rarely practical.** Scald may be controlled better by prompt cooling and by absorption of toxic volatiles by oiled wraps.

Removal of these volatiles from the storage atmosphere by circulating it over activated charcoal is being investigated as an alternate method.

Circulation of the air within the storage room is recommended to secure and to maintain uniform temperatures in different locations in the room and in the individual blocks of fruit. Where there is little or no air movement, fruit temperatures may vary considerably in different parts of the room. The regular reading of a number of thermometers at different locations in the room and between stacks of fruit will enable the operator to discover the warmer locations where more air circulation is desirable, also to guard against possible freezing of fruit near the coils or air intakes. Maintaining an average room temperature of 30–31 F demands **close temperature control.**

For long life of fruit **prompt cooling** is essential. Apples soften approximately twice as much at 70 as at 50 F; twice as much at 50 as at 40 F and about twice as much at 40 as at 32 F. Even with small stacks of apples in a room where the air is constantly maintained at 32 F, three to four days may be required to reduce the temperature of the apples in the center of a packed box from 65 to 34 F. Cooling the fruit to 31 to 32 F will require another two or three days with air at 29 to 30 F. In commercial storage rooms maintained at 32 F, two weeks may be required to obtain a fruit temperature of 34 F in the center of large stacks of apple boxes.

Slow cooling may be due to inadequate refrigeration capacity, especially if large blocks of warm fruit are received at one time; to close stacking; to lack of sufficient air movement; and to excessive loss of refrigeration through open doors when fruit is received intermittently over a period of several days or weeks. Obviously apples that are wrapped and packed will cool more slowly than those stored loose in boxes or open crates.

It is easier to maintain optimum storage conditions after they have been established than it is to attain them during the critical period when warm fruit is being received. Bad effects of delayed cooling are not evident at the time, but are inevitable, so that every effort should be made to secure **rapid cooling.** This can be accomplished by placing the fruit in **precooling rooms** before storage or by providing sufficient air movement and refrigeration in the storage rooms to get the desired results. For maximum storage life, especially for the early-season and more rapid ripening varieties, precooling is advantageous. It is usually required for fruit that is to be exported.

During storage and ripening, apples give off ethylene and other volatiles which (probably) hasten the ripening processes. Fruit of advanced maturity give off more

of these volatiles than less mature fruit. Therefore apples intended for long holding should be stored separately from earlier ripening or more mature fruit.[30]

With every possible precaution taken to insure good keeping quality of apples, unforeseen circumstances and unexpected results may occur. Some special condition may arise making it desirable to remove the fruit from storage before the end of its normal storage period. On this account the fruit should be inspected regularly and carefully throughout the time it is in storage.

The storage life of apples is affected not only by the conditions under which they are stored but also by the conditions under which they are grown and handled prior to storage. Predicting the keeping quality of any lot of apples is therefore difficult. However, barring any special cause which may shorten their life, good apples, properly stored, normally can be held at 30–31 F for approximately the periods shown in Table 1. Maximum holding periods exceed the above limits by from one to three months but the longer the storage, the shorter will be the period during which the fruit may be distributed to the consumer in good condition.

Table 1. Storage Life of Apples at 30–31 F

Jonathan, Grimes Golden, and McIntosh	2–3 months
Golden Delicious, Cortland, Rhode Island Greening	3–4 months
Baldwin, Delicious, Stayman Winesap, York Imperial, Arkansas, Northern Spy, Rome Beauty, Ben Davis	4–5 months
Winesap, Yellow Newton	5–7 months

Modified atmospheres offer a means of lengthening the storage life of varieties susceptible to low temperature injury, and which therefore should be held at 36 to 40 F.

There are numerous "gas storages" in England and an extensive one at Elgin, C. P., South Africa. In this country storage of McIntosh in modified atmospheres is now commercially practiced to a limited extent in New York State. Commercial trials have been successfully conducted with the Yellow Newtown in California and extensive experimental tests with Jonathan in Iowa and McIntosh in Canada.

In commercial practice modified atmospheres are secured by filling gas-tight cabinets or rooms with fruit and permitting respiration to diminish the oxygen content of the air and build up the carbon dioxide concentration. For each part of oxygen consumed approximately one part of carbon dioxide is liberated. Respiration is allowed to continue without ventilation until the oxygen is reduced to the desired amount, this being controlled subsequently by ventilation. Should the carbon dioxide concentration be higher than desired, the excess may be removed by circulating the "air" through a washer or "scrubber" filled with 30 percent sodium hydroxide solution.

Different varieties of apples and even the same variety grown in different localities may respond somewhat differently to the same proportions of carbon dioxide and oxygen in the atmosphere, and experimental work is being conducted to determine the effects of different atmospheres at different temperatures. Essentially equal parts of CO_2 and O_2(10.5 percent CO_2 and 10.5 percent O_2) have been found to be very satisfactory concentrations for the Bramley Seedling in England and also for Yellow Newtown in California. For most apple varieties a relatively low concentration of carbon dioxide and a reduction of the oxygen content to the minimum capable of supporting respiration appear to give the best results.

Because of the difficulty and expense of making storage rooms air-tight, the extra attention required to maintain the atmospheres at the proper concentrations, the desirability of keeping the room closed and undisturbed for long periods, and the necessity of supplying workers in the room with oxygen for breathing, use of controlled atmosphere is not feasible in large commercial cold storages, and promises to be limited largely to farm storages

and to that part of the crop which responds unfavorably to long holding at 30–32 F.

For detailed information on the results of experimental work with modified atmospheres for storage of apples see references 4, 9, 11, 24, 33, and Chap. 44.

Harvesting and handling before storage. The time of harvesting and the methods of handling apples between the orchard and the storage are important factors in the storage life of the fruit, particularly in regard to the more important physiological or "storage" diseases. **Proper maturity** at harvest time is highly essential. If picked in an immature condition, the fruit is subject to excessive moisture loss and shriveling, and susceptible varieties are subject to severe development of apple scald and bitter pit. If allowed to remain on the tree too long, apples are more subject to water core, decay, and premature old age or breakdown.

After the fruit is removed from the tree it should not be held in the orchard or packing house longer than absolutely necessary before being placed in cold storage. Although there is some indication that a few days' delay between harvest and storing of fruit may reduce the severity of disorders like brown core in McIntosh, **delay in cooling,** either before or after the fruit reaches the storage room, **invariably shortens** the **normal storage life.** It has been shown by a number of investigators[13,18,27,29] that a three or four days' delay at 60–70 F may decrease the storage life of apples at 43 F as much as one month.

Handling methods both in the orchard and packing house and also in hauling have an important influence on storage life. Rough and careless handling in hauling or in the packing house results in bruises, skin breaks, and stem punctures, which may be overlooked at the time but often result in premature breakdown or mold infection. Frequently apples are shipped to market centers before storage. In other instances shipment may be made during the middle of winter. In fruit that is shipped long distances to storage, the life of the fruit may be shortened by high transit temperatures or by freezing unless it is properly protected in transit. Every precaution should be taken to avoid these extremes of temperature.

Storage troubles. Aside from fungous rots, apples held for a number of months in storage are likely to develop one or more physiological disorders. Storage conditions may or may not be responsible for these troubles, but since they manifest themselves in storage they are most commonly referred to as storage troubles. Often the basic cause of these diseases is either inherent in the apples or is due to faulty harvesting and handling before the fruit is placed in the storage room. While some of these matters are beyond the control of the cold storage warehouseman, he should familiarize himself with the causes and methods of control of disorders likely to be encountered. (See references 4, 10, 26, 27, also Chap. 19.)

The diffuse browning of the skin of apples known as **apple scald** is perhaps the most widespread physiological disease of apples. Arkansas, Stayman Winesap, Grimes, Rome Beauty, and Rhode Island Greening are particularly susceptible. It also occurs on other varieties, especially when harvested early in the season or with poor color development. Delayed storage and storage temperatures above 32 F also favor its development.

Scald usually affects only the skin and therefore only the appearance of the apple, but may, in advanced stages, extend into the flesh. Fruit showing scald in storage is likely to have the trouble markedly increased within a few days after it is removed to room temperature. As scald is a result of certain toxic gases given off by the apples themselves, it can be greatly reduced by absorbing these gases in oiled wraps or by the use of shredded oiled paper well distributed throughout the container.

Experimental trials in the removal of fruit volatiles from the storage atmosphere by repeatedly passing it over finely divided particles of activated charcoal have given good results in some experimental trials.[31,32,34,35] More extended tests will be needed before it can be recommended for

commercial use. Preliminary holding of fruit for several days in an atmosphere of 25–50 percent carbon dioxide has also given results in the control of scald on some varieties but few, if any, commercial storage houses are equipped for offering this treatment.[2,23,31,34]

Soft scald, which is distinctly different from ordinary scald, is characterized by blister-like or burned-appearing areas extending in irregular patterns over the fruit. The affected areas are usually brown in color, slightly sunken, and with definitely outlined edges. The flesh beneath such areas is often soft and discolored to a slight depth. Jonathan, Rome Beauty, and McIntosh are the most susceptible varieties, but soft scald may also occur on Cortland, Winter Banana, Golden Delicious, Northwestern Greening, and other varieties. The exact nature and cause of the trouble are unknown, but it is associated with low-storage temperatures and advanced maturity. Holding at 36 F if the fruit is well matured or over-mature when harvested is usually recommended, although the trouble appears to be reduced or prevented also by early harvest and immediate storage at 30–32 F.

Again as with ordinary scald, Brooks and Harley[5] were able to commercially control soft scald on Jonathan and soggy breakdown on Grimes Golden by subjecting the fruit for several days before storage to atmospheres containing 25–35 percent carbon dioxide.

Soggy breakdown is a disease very similar to soft scald in cause but manifests itself in a soft watery or soggy breakdown of the flesh, often without any external symptoms. The disease is most severe on Grimes Golden and Golden Delicious, and storage at 36–38 F is generally recommended to prevent its occurrence.

Internal breakdown is a brown, dry, mealy disintegration of the flesh characterizing the end of normal storage life of apples. In advanced stages, the skin is also discolored, and the flesh becomes soft. Large apples are usually the first to show this condition. Over-maturity at time of harvesting, delayed cooling, and high storage temperatures are the primary factors inducing early breakdown. It often follows water core and freezing.

Jonathan spot is manifested as dark colored, superficial spots in the skin of the fruit and is most prevalent on the Jonathan variety. It is associated with over-maturity, delayed storage, high storage temperatures, and long holding. The colored side of the fruit is more susceptible than the uncolored.

Shriveling is the visible evidence of excessive moisture loss from the fruit and is due primarily to too low humidity of the storage atmosphere. Fruit harvested in an immature condition loses moisture more readily than that which is allowed to become fully mature.

Internal browning differs from internal breakdown in that the discoloration, which at first is confined to elongated areas radiating from the core in the upper half of the apple, appears while the flesh is still firm—usually by early January. Later the entire flesh may become brown. The trouble is of most economic importance on Yellow Newtowns grown in the Pajaro Valley of California. The **brown core** condition, important in McIntosh apples in New York and New England, is similar if not identical. Unlike internal breakdown, these two disorders are induced by minimum storage temperatures. Little development occurs at 36 F and none at 40 F. Both McIntosh and Yellow Newtown respond well to modified atmosphere storage at these temperatures. Delaying the storage of susceptible varieties for 5 to 10 days reduces the severity of the trouble but this delay at atmospheric temperature shortens the period during which the fruit can be held.[4,27]

PEARS

After harvest and while in storage, pears undergo the same general ripening changes as apples, but in most varieties, particularly the Bartlett, the changes are more rapid. Speed in handling and quick cooling are therefore even more essential for keeping quality than is the case with apples.

Temperatures and storage conditions. Thirty to 31 F is recommended for storage of fall and winter varieties, and 29 to 30 F

for the more rapid ripening Bartlett. The average freezing temperature of Bartlett is 28.5 F; hence, **29.0 F** is practically the **minimum** at which they can be held without freezing. However, this is usually a safe air temperature to maintain because the actual fruit temperature of packed pears is usually one degree or more above room air temperature; also, slight freezing of Bartlett pears for limited periods is not detrimental. Thus far no low temperature storage injury has been recognized; however, the length of time the fruit is held in storage, and subsequent ripening temperatures are important considerations for proper ripening and good quality. These matters are discussed subsequently.

Pears **lose moisture** even more rapidly than most varieties of apples; hence every effort should be made to hold the relative humidity at a minimum of 90 percent. Where the air is circulated at the rate of 100 ft per min or more in the aisles, 95 percent humidity is recommended.

As in the storage of apples, ventilation aside from that which normally occurs when workmen go in and out of the rooms is impractical, but some air movement within the room is desirable.

For best results in the storage of pears, special attention needs to be given to their **initial cooling.** The fruit is frequently received for several days in succession in large quantities and at high temperatures. To remove the field heat quickly, especially if the fruit is packed, requires extra refrigeration capacity and the best efforts of the storage engineer. Cooling is most rapid in rooms having good air circulation. For initial cooling, the air may be carried as low as 25 F for several days when close attention is given to avoid freezing. When a number of days are required for filling a room, the first fruit received should be placed near the delivery air ducts, and warm fruit subsequently received should be stacked in front or nearer the return air ducts to prevent rewarming the earlier stored fruit. Ripe pears should not be placed in cold storage. Their storage life is very short at best; moreover, they give off ethylene, which will hasten ripening of other fruit.

On account of the wide variation of temperature that exists in many storage rooms while the fruit is being received, readings of both air and fruit temperatures should be obtained frequently in different parts of the room to ascertain the rate and uniformity of cooling. Slow cooling areas, where ripening would be accelerated, and cold pockets, where there is danger of freezing, can thus be located and often corrected by the use of **portable fans.** Once all the fruit is reduced to the desired storage temperature, close control at 29 to 31 F is necessary to avoid freezing.

The storage life of pears is limited by such factors as (a) overripeness, (b) core breakdown, and (c) loss of ripening capacity. Successful storage depends not only upon quickly attaining and then maintaining proper storage temperature and humidity, but also upon the maturity of the fruit when harvested, methods of handling, and the time required for the initial cooling.

Fruit harvested when immature is subject to excessive water loss and subsequent shriveling. Overmaturity quickly results in overripeness, often accompanied by scald and core breakdown. The rapidity with which the fruit is cooled to storage temperature after harvest has a most important bearing upon its subsequent storage life. For this reason pears to be held long or to be shipped far, either previous to or after storage, should be **precooled.** In some of the more modern storage houses that specialize in the handling of large quantities of pears, this precooling can be done in the regular storage rooms. Some of these rooms are comparatively small in size and are designed for independent air circulation and temperature control. Cold air is circulated rapidly over and through the stacks of fruit for a number of days, after which the air velocity is reduced and the temperature raised to that desired for holding. Hydrocooling, extensively used for certain vegetables, is now being successfully employed for precooling cannery stock of Bartlett pears and peaches before storage. Field lugs of loose fruit placed on an endless draper running through one or

two 20′–25′ hydrocoolers pass under a strong flood of ice water for a period of 10–20 minutes. By maintaining the temperature of the water below 35 F by the constant addition of crushed ice heat transfer from the fruit is exceedingly rapid. An initial fruit temperature of 75–85 F is reduced to below 50 F in 20 minutes or less. Such rapid cooling of each individual fruit results in a much lower and more uniform initial fruit temperature in the storage room than is practical by any other means. Table 2 indicates the storage life for the more important pear varieties if the fruit is well precooled.

Table 2. Storage Life of Pear Varieties

	Stored immediately at 30–31 F	Stored at 30–31 F after precooling and 10–12 days in transit
	Months	Months
Bartlett	1½–3	1½–2
Comice, Hardy, and Kieffer	2 –3	2 –3
Bosc	3 –3½	2 –3
Anjou	5 –6	4 –5
Winter Nelis	6 –7	6 –7

Naturally the keeping of pears following shipment is dependent upon the extent of precooling and the fruit temperatures maintained in transit. **Transit temperatures** should be 45 F or lower during shipment to Eastern markets from the West Coast. Lower and more uniform temperatures than those previously found in refrigerator cars are now possible in the newer type cars equipped with Preco fans. (See Chapter 22.) If the fruit is to be stored after shipment, the closer it can be kept to 32 F during transit, the better.

Some differences are noted in **keeping quality** of pears from different sections of the country, those from sections having relatively cool growing temperatures having a shorter life. These differences do not always manifest themselves in storage but may become quickly apparent after the fruit is removed to higher temperatures for ripening. Storage warehousemen who may not be familiar with the characteristic keeping quality of pears from different districts might find it advantageous to obtain this information on fruit offered for storage.

Regardless of where grown, Bartlett, Bosc, and Comice, if held in storage too long, will lose their capacity to ripen normally. Anjou and Winter Nelis do not. Loss of **ripening capacity** takes place earlier at 36 F than at 30 F. When ripening is attempted after too long cold storage the pears may become yellow, but they remain hard. Scald and breakdown may appear on Bartlett and Comice. When the Bartlett variety begins to show yellow in storage it is a sign that it has been held too long. The other varieties will show no external symptom of overstorage. The best way to avoid this trouble is not to store them longer than the maximum time indicated for the variety. Bartlett pears should be removed from storage while still having a slight green color, and be allowed to ripen at higher temperatures, 60 to 65 F being optimum for Bartlett as well as other varieties. In all attempts to hold pears for their maximum storage periods, it should be remembered that even though the external appearance remains good, dessert quality is deteriorating. Studies with Bartlett pears from the Pacific Coast states[19] showed that fruit held in cold storage at 31 F for only 30 days ripened with quality almost equal to that ripened immediately after harvest. Fruit held for 60 days was somewhat poorer, whereas that held for 90 days or longer was generally of only fair quality.

Modified atmospheres. Since Anjou, Bosc, Comice, and Winter Nelis pears are available through the winter, little interest has been taken to date in extending the normal storage of Bartletts. However, if the demand for this variety extends into the winter, modified atmosphere storage appears to offer commercial possibilities. The results of British investigations[14] have been confirmed in California[1] where the normal storage life of the Bartlett at 31 F has been doubled by holding it in an atmosphere of 5 percent CO_2 and 2.5 percent O_2. For shorter storage periods, such a combination gave as good results at 36 F as were obtained when the fruit was stored in air at 31 F, and as good results at 45 F as in air storage at 36 F.

Oxygen reduction to 1 or 2 percent, even without the addition of carbon dioxide has also materially extended the normal storage period.[3]

Storage troubles. Although **core breakdown** is likely to be more serious in pears from some districts than from others, it occurs widely. It is characterized by a breaking down of the tissues in the core area and may spread to the entire fruit. At first, the flesh is soft and watery. Later it turns brown, and the skin of the fruit may also become discolored. Affected fruit has a foul, sickening odor and flavor. Core breakdown is definitely associated with harvesting in an overmature condition and with delayed cooling. Bartlett, Hardy, Bosc, and Comice are the important varieties that are especially susceptible.

Anjou scald is similar in appearance to apple scald and is apparently induced in part by the same factors; like apple scald it can be controlled by use of oiled wraps.

The ordinary form of **pear scald,** however, is usually associated with core breakdown and apparently is due to prolonged holding in storage. It is not controlled by use of oiled wraps. The time when pear scald appears depends upon storage temperatures. Bartletts which may be free of scald after even 90 days at 30 or 31 F are likely to show it in 70 to 80 days at 36 F or in 30 to 35 days at 43 F. Bartlett and Bosc are the most susceptible varieties.

Although pears may color at low storage temperatures, they do not always soften or ripen. This is true of Bartlett, Bosc, and Comice; if held in storage too long, they lose their ripening capacity and will fail to ripen even after removal to suitable ripening temperatures.[12]

Pears may occasionally suffer **freezing injury,** but, in the Bartlett variety at least, unless this is severe or prolonged, no subsequent damage seems to occur. A trouble of much more common occurrence is a wilting or shriveling of the fruit as a result of excessive moisture loss. A relative humidity of above 90 percent will hold the fruit in good marketable condition although an atmosphere approaching saturation is necessary to prevent moisture loss entirely.

Where fruit is carefully handled and graded before storage, **fungous rots** in pears are usually not serious. However, Anjou, and Winter Nelis, when stored for long periods, may suffer serious loss from **gray mold rot** (*Botrytis sp.*). This trouble is also known as cluster rot because a large number of affected fruits are frequently found in one position in the box surrounding the original infected pear. The fungus grows from one pear to another at cold storage temperatures. Infection may be reduced by good sanitation in the packing house, careful handling, and prompt cooling, but the most effective control measure is use of copper-treated wraps for packing to prevent the spread of the disease from infected pears to adjacent sound fruit.

For other pear diseases, see Chap. 19.

GRAPES

Grapes "live" relatively slowly, and should be properly matured before harvesting because they do all of their ripening on the vines before harvest instead of continuing it in storage as do apples and pears.

Grapes have more natural resistance to storage rots if picked as soon as fully mature and before they have been wet by rain.

Temperature and storage conditions. Recommended storage temperatures for vinifera grapes are 30 to 31 F.[21] Although temperatures as low as 28 F have not been injurious to well-matured fruit of some varieties, other varieties of low sugar content have been damaged by exposure to 29 F.[6,7] A humidity of 87–92 percent at temperatures of 30 to 31 F is recommended for the storage of grapes.

Storage plants in California that specialize in holding grapes provide good air circulation in the rooms. Some have **precooling rooms** where the grapes are cooled to 36 to 40 F in 20 to 24 hr before they are placed in storage. In most plants all of the cooling is done in the storage rooms, but only a few have sufficient air movement to cool the fruit as quickly as desired. Experience has indicated that about 4,000 to 6,000 cfm per carload of fruit is needed in rooms used for precooling. After the fruit has been precooled, the air velocity should be reduced to that

which will maintain uniform temperatures throughout the room.

In the storage of grapes there is no need for ventilation except to provide for exhausting sulfur dioxide-laden air following fumigations, as will be described later. Accumulation of carbon dioxide would not be objectionable and might benefit the grapes.[8] Grapes do not give off appreciable amounts of ethylene or other substances that accelerate ripening as do apples, pears, and some other fruits.

The normal change that takes place in grapes in storage involves chiefly loss of water. The most noticeable effect of this is drying and browning of stems and pedicels and shriveling of the fruit. Grapes become slightly sweeter during storage due to concentration of sugar by loss of moisture, but the total amount of sugar present slowly diminishes as does the acid content as well.[20]

Since the turgidity of grapes increases as the temperature is lowered, they sometimes split in storage. With prolonged holding, moisture loss eventually causes the fruit to lose its turgidity and to soften. During storage the pedicel attachment becomes weakened, probably as a result of changes in pectic substances; consequently shattering (loss of berries from the stem) is sometimes a problem on susceptible varieties such as Sultanina (Thompson Seedless). The color of red or blue varieties gradually becomes darker in storage. White varieties, such as Ohanez, Sultanina, and Malaga, may turn brown. This browning becomes worse with longer storage and cannot be prevented by storing at 36 F instead of 31 F. Browning of white varieties is also sometimes associated with over-maturity, and fruit from one vineyard may be more severely affected than that from another.

Fumigation. Grapes are usually stored in rooms by themselves, for if they are to be held more than a few weeks they should be fumigated for mold control with sulfur dioxide, which is injurious to other storage commodities. If the fumigation is done on a concentration basis, sufficient gas is introduced into the room to equal $\frac{1}{4}$ percent by volume. The total capacity of the room is calculated, and from this is subtracted the space occupied by the grapes, which will be roughly equivalent to $\frac{1}{2}$ cu ft per lug, when air voids between grapes are taken into account. Since 1 lb. of SO_2 is equivalent to $5\frac{1}{2}$ cu ft of gas at 32 F, the free space in the room multiplied by $\frac{1}{4}$ per cent divided by $5\frac{1}{2}$ will give the pounds of gas needed.

Free space (cu ft) $\times \frac{.0025}{5.5} =$ lb of gas needed.

The cylinder containing sulfur dioxide is warmed in boiling water as the gas is released from it. The valve should be opened as soon as the cylinder is placed in the hot water to prevent the high pressure generated from blowing out the safety plug. The gas is introduced quickly into the room through special nozzles which are installed about 6 ft apart along the ceiling above the aisle. Meanwhile, large fans are used to mix the sulfur dioxide with the air in the room. After 25 to 30 min exposure, the room should be cleared of the sulfur dioxide laden air. The fumigation should be repeated every week or 10 days.

When the gas needed is estimated instead of calculated on a concentration basis, $\frac{3}{4}$ to 1 lb of gas is used for every 1,000 lugs of grapes in the room, the exact amount used depending upon the susceptibility of the grapes to injury. Until the room is half filled with grapes, an additional $\frac{1}{4}$ lb of gas is used for each carload unit of empty space (1300 to 1500 cu ft). After it is half full no gas is added for the unoccupied space. The room is cleared of gas after one hour fumigation. The air in the room should be circulated during fumigation as in the other method, and the fumigation should be repeated at least every week or 10 days.

In plants that are devoted entirely to the storage of grapes the gas is sometimes released into the air ducts of the plant, thus utilizing the air cooling system for even distribution and good circulation in the rooms. If a brine spray system of refrigerating the air is employed, a bypass should be installed around the spray chamber so that the gas does not come into contact with the wet metal surfaces, since it readily forms a corrosive acid in combination with water. For the same reason sulfur dioxide should be cleared from the

air of the rooms before the damper is turned and the air is circulated through the spray. It is advisable to check the acidity of the brine frequently to guard against corrosion.

Sulfur dioxide has certain properties that demand **care** in its use as a fumigant in cold storage plants. The concentrations recommended for the fumigation of grapes in storage, about 0.25 percent, can cause respiratory spasms and death if the victim cannot escape from the fumes, while concentrations as low as 0.04 percent are irritating and can injure the mucous membranes. Washing the mouth, nose, and eyes with water alleviates the discomfort. A few drops of dilute ephedrinal sulfate solution, such as is ordinarily used, will give relief when applied in the nose. When working in even weak concentrations of sulfur dioxide, one should wear goggles to protect against injury to the eyes, and a gas mask fitted with canister for acid gases (not the usual canister for ammonia gas) should be used. Concentrations as low as 30 to 40 parts per million can be detected by smell. It requires several times these concentrations to cause discomfort.

A second property of sulfur dioxide which cannot be overemphasized is its injurious effects on other produce. For this reason, care must be taken that only grapes are stored in the room that is to be fumigated, and also that there are no leaks through walls or halls to adjacent rooms containing other produce.

A third property of sulfur dioxide that demands emphasis is its corrosive action on metals, particularly iron and zinc which are commonly used in the construction and coating of coils, brine spray chambers, etc., in cold storage plants. Use of acid-resistant paints on exposed metals is helpful in reducing this corrosive action.

Periodical inspection of the fruit to see whether the sulfur dioxide gas is reaching the center of the stacks or whether some grapes are being overtreated is recommended. If the pedicels and stems retain a yellow or green color and if broken berries show no mold and appear to be dried or seared, the gas has reached the fruit in question and is having the desired effect. When serious bleaching is observed on unbroken grapes, the concentration has been too high or the exposure too long, and there should be better distribution of the gas, lower concentration, or shorter fumigation periods.

The most common cause of loss in grape storage is **gray mold rot** (*Botrytis sp.*). Prompt cooling, constant low temperatures of 30 to 31 F, and regular fumigation in storage are the chief aids in controlling it. Rains or foggy weather during harvest are the important contributing factors in starting gray mold infections. When inclement weather gives reason to question the storage quality of grapes, the inspection of incoming lots of fruit is a wise precaution against unjustified storage claims. Often incipient infections of gray mold, called "slip skins," can be found on grapes several days after they have been wet by rain.

The normal storage life of the principal varieties of California table grapes at 30 to 31 F is shown in **Table 3.** Under exceptional conditions sound fruit will keep longer than indicated; for example, Emperor grapes have been held in good condition for seven months, and Sultanina for four months.

Table 3. Storage Life of California Table Grapes

Emperor, Ohanez, Alphonse Lavallee (Ribier)	**3–5 months**
Malaga, Castiza (Red Malaga), Cornichon	**2–3 months**
Sultanina (Thompson Seedless)	**1–2½ months**
Flame Tokay, Alexandria (Muscat)	**1–1½ months**

The storage life of grapes is affected in large degree by the attention given to selecting and preparing the fruit. Grapes should be picked at the best maturity for storage, especially Sultanina and Ohanez. Stems and pedicels should be well developed and the fruit should be firm and mature. Soft and "weak" fruit should not be stored. The display lug is a satisfactory package for storage since it can be cooled and fumigated easily. Sawdust packages cannot be fumigated effectively, so that it is necessary to fumigate the grapes before they are packed. South African packs of wrapped bunches in excelsior have proved

to be good storage packages. Precooling to 40 to 45 F is advised for grapes that are to be in transit a day or two before reaching storage. Special care should be taken that good transit refrigeration practices are used for grapes shipped to storage so that decay will not get started. Grapes intended for storage, except those in sawdust packages, should be fumigated when shipped. It is not good practice to delay fumigation until the grapes reach a distant plant, for in the picking and packing of grapes many berries are injured sufficiently to permit mold to get started unless the fruit is fumigated promptly.

For Eastern varieties of grapes[28] storage temperatures of 31 to 32 F and humidities of 80 to 85 percent are recommended. Care in packing and handling the fruit, a minimum of delay before storage, and prompt cooling are important for best results with these varieties as they are with the vinifera or California grapes.[16] The Eastern varieties are not fumigated with sulfur dioxide because of their susceptibility to injury from it. The storage life of the important commercial varieties at 32 F is shown in Table 4.

Table 4. Storage Life of Eastern Grapes

	Weeks		Weeks
Concord	4 to 7	Catawba	5 to 8
Niagara	3 to 6	Worden	3 to 5
Delaware	4 to 7	Moore	3 to 6

Design and Operation of Fruit Storage Houses

The refrigeration required for fruit storage houses involves the customary consideration of (a) losses through walls, ceilings and floors, (b) air leakage by infiltration and opened doors, (c) heat given up by the product when it is cooled, (d) heat given off by the product through respiration, and (e) miscellaneous sources of heat such as motors and men working in the rooms. (See also Chap. 13.)

The performance of the storage plant will depend in a large measure upon (a) the provision of adequate capacity in compressor, condenser, and cooling tower for peak loads; (b) sufficient evaporator and secondary refrigerating surface to permit operating at high back pressures, thus preventing low humidities and permitting economical operation; (c) efficient air distribution, with velocities high enough to effect rapid cooling of warm produce and volume great enough to permit operation during storage with only a small temperature rise between incoming and outgoing air.

In making the best use of available refrigerating equipment, the construction of the storage building is of great importance, particularly in respect to (a) floor plan for convenience in loading and unloading, (b) design for ease in getting refrigeration to the various rooms, (c) insulation, its composition, thickness, and proper application.

The pertinent information the refrigerating engineer will require in designing the plant will be:

a. Cooling load; the temperature of incoming fruit, final temperature desired in a specified time, daily volume to be cooled, heat given off by respiration of the fruit, kind of commodity, and package.

b. Storage load; the temperature and humidity desired, permissible variation in temperature of the fruit throughout the room, volume to be stored and respiration rate of the commodity.

c. Heat of respiration or vital heat; with apples and pears, particularly.

d. Heat leakage; outside temperature during cooling and storage season, insulation used, method of construction, area of exposed surfaces.

e. Miscellaneous; loading and unloading schedules, number of workmen in the rooms, lights, motors, etc.

Systems generally used. Many of the older storage plants have rooms equipped with either brine or ammonia coils attached to the ceiling or walls. Air circulation in these plants is provided by natural convection which leaves much to be desired in respect to rapid cooling and providing uniform temperature throughout the room. These shortcomings have been overcome in some instances by enclosing the coils with baffles and installing fans to provide positive circulation of air from the storage room over the coils. Rooms that are indi-

vidually refrigerated have several advantages as compared to those on a common air bunker. They can be operated as individual units in respect to temperatures or humidities or fumigation treatments without affecting the rest of the plant. Individual unit coolers are suitable for small rooms, but when installed in large rooms should be used with some system of ducts to give good air distribution.

Many of the fruit storage plants constructed in recent years employ **brine sprays** as a means of providing a large cooling surface at low cost. The cooling unit usually consists of a bank of ammonia coils over which brine is sprayed. Air from the storage rooms is circulated through the spray chamber and is discharged into ducts that supply the storage rooms. A suitable brine eliminator is used to prevent droplets of brine from being carried into the air ducts. In some plants a similar air cooling and circulating system is used in which the bunkers have dry coils to take the place of the brine spray.

Ice bunkers have been used in some fruit storage plants either as a means of cooling the storage rooms in case of breakdown of the mechanical refrigerating machinery, or to take care of peak loads such as are called for in precooling. The bunkers are sometimes built along one side or end of the storage room and fans are installed that circulate air from the bunkers to the storage space.[15] Suitable air temperatures can be obtained during precooling by salting the ice. After the fruit has been cooled, mechanically refrigerated **unit coolers** are used to maintain desired temperatures. Some ice is usually left in the bunkers and several of the bunker fans are operated intermittently during storage to hold humidities at 87 percent or higher. Several modifications of this type of installation have been made, including the use of refrigerated coils in the ice bunker with a lengthwise partition between the ice compartment and the coils, so that by means of a damper, air can be circulated with the bunker fans either through the ice bunker or past the coils. An ice bunker of this type is sometimes installed in centrally refrigerated plants in such a manner that it can be used in lieu of the brine spray chamber or in conjunction with it to cool the air delivered to the storage rooms.

Temperature and humidity records. Temperatures are commonly taken in fruit storage rooms by a thermometer hung in the aisle or on one of the walls. Unless the storage operator has established the fact that temperatures are uniform throughout the room, such readings are likely to be misleading and inadequate. To see that all parts of the room are at the desired temperature, readings should be made at several places. A record of air and fruit temperatures in the various storage rooms is information that the operator needs to determine the performance of the plant. This information can be obtained with glass fruit thermometers at the expense of space or labor to get to the middle of stacks of fruit; but it can be done more conveniently with distant reading thermometer equipment such as thermocouples or electrical resistance thermometers, with which some storages are equipped.

Storage instructions or recommendations usually specify a rh within a range of 3 to 5 percent. It is exceedingly difficult to read humidities as closely as this with the ordinary sling psychrometer at temperatures of 32 F or lower. One-half degree error in reading either the wet or the dry bulb thermometer will cause an error of 5 percent rh. Carefully calibrated thermometers graduated to 1/10° with a range of 25 to 40 F are best adapted for this purpose in fruit storages. A convenient device for measuring humidities consists of a pair of these thermometers, mounted in a short length of metal casing attached to a spring or motor operated fan which draws air past the thermometers at a speed of 3 ft per sec or faster. To get dependable readings, the thermometers should be placed so that they will not be heated by the warm fan motor, and they should be read quickly to prevent warming. The advantage of this instrument over the sling psychrometer is that it can be left in the room long enough to get a true wet bulb reading. This may require 15 min or more if ice is formed on the wet bulb. Under these conditions, a thin coating of ice is preferable to a thick one in getting accurate readings. Hair hygrometers are satisfac-

tory if not subjected to sudden large changes in humidity and temperature and if checked regularly with a psychrometer.

Stacking fruit in storage rooms. Apple and pear boxes are generally stacked on their sides in storage rooms although occasionally pear boxes are stacked on their ends. Grape lugs are stacked upright. Dunnage strips of 1- by 2-in. material are placed between each two layers or every few layers to bind the stacks and to provide air spaces between layers. Channels about 2 to 3 in. wide are left between rows of packages. The packages should be loaded lengthwise to the channels so that their tops and bottoms or sides are exposed instead of the tighter, thicker ends of the packages. If the room is provided with cross movement of air, the channels should be parallel to the air direction in order to promote good air distribution throughout the room.

Cleats are sometimes nailed on the sides of pear boxes to permit stacking without the use of dunnage strips and some grape lugs are made with thick cleats on the lids that are tapered to compensate for the bulge, thus permitting these packages to be stacked squarely without dunnage strips between layers.

Bushel baskets are usually stacked so that the packages are not directly above one another but are offset. Dunnage strips are used to hold the rows and stacks together.

When fruit is stacked on pallets in storage rooms the packages should be spaced so they can be cooled. Dunnage strips are commonly used between each layer of grape lugs and channels of $\frac{3}{4}$ inch or more are left between the sides of the lugs. Cannery fruit is usually stored in unlidded cleated lugs and there is good access of air to the fruit, hence channels are not left between lugs. Pears are often stored on end and the bulge of the boxes keeps them spaced well enough for fairly good ventilation.

Incoming fruit should be inspected to determine its suitability for storage. This inspection will afford a protection to the storage firm against accepting fruit in poor condition for storage, and it will likewise render a valuable service to the owner of the commodity who may not be aware of the condition of the fruit sent to the storage plant. Periodical inspection during the storage period should also be made a part of the storage practice.

Removal from storage. When fruit is removed from storage, care should be taken to prevent undue warming and condensation of moisture which favors decay and deterioriation. Most storages are built on railroad sidings, and canvas tunnels should be provided between the car and the storage through which the fruit can be conveyed so as to reduce to a minimum the warming of the fruit and condensation of moisture upon it.

When fruit is removed from storage for distribution to wholesale and retail markets, there is little that the storage operator can do to prevent undesirable condensation. Warming the packages until they are above the dew point of the air would prevent it, but this takes time and space and is seldom practicable. Deterioration in flavor and condition proceeds rapidly after long storage periods. Decay likewise develops quickly in fruit after removal from storage. Therefore, the fruit should be moved to consumers as rapidly as possible.

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If you searched this chapter for something which was not found in it, please let the editors know.

16. CITRUS FRUITS*

Harvesting and Packing-House Handling

PROPER picking and handling of citrus fruits in the orchard and packing house involve many operations that have been continually improved for more than 50 years. The "packing-sheds" of the early days have been replaced by well designed and substantially constructed packing plants. These are now equipped with modern machinery for handling the fruit in a careful and economical manner. The art of good handling has gradually changed from a strictly laborious task to one involving scientific knowledge and technical skill. In general all citrus fruits require the greatest care in handling to prevent mechanical injury, excessive deterioration, and decay.

Picking. In California citrus fruits are harvested throughout the year. Picking is largely in the hands of the packing associations, and is performed by trained crews. It has been found that the associations can organize and perform the work better and more efficiently, and keep picking policies in better line with the market situation, than can the growers.

Special **wooden field boxes** with tight bottoms are provided to prevent the entrance of orchard dirt, and are kept in repair and free of rot residues, dirt, litter, splinters, and protruding nails. **Canvas picking sacks** of the "closed-mouth" type, holding approximately a half box of fruit, are now commonly used. Clippers of special design are used and ladders are provided for picking fruit beyond reach. Gloves are required during picking to avoid finger nail injuries to the tender rind.

Picking is discontinued when trees are wet to avoid **green-spotting** due to oil liberated from the rind and, whenever possible, for a period of several days following severe hail or wind storms, or after excessive frost or heat damage has occurred, to allow healing of injuries and to give time for evidence of damage to appear so that when picking is resumed better grade separation is possible.

The fruit is cut from the stem just above the button. When lemons are picked two cuts are required, one with a short length of stem attached, the second close to the button. Much attention is paid to the quality of work performed and inspection is maintained to avoid "long stems," "clipper cutting" of the rind, and "pulling." Cutting of the lemon button should be avoided.

Lemons are picked by the aid of **"rings"** designed for the purpose of selecting fruit

J. R. MACRILL, Co-author Chapter 16. Formerly with the Leffingwell Rancho Lemon Assn., 4 years; California Fruit Growers Exchange, 21 years; Manager Field Laboratory, California Fruit Growers Exchange, 14 years.

Author of several papers for California Citrograph on citrus fruit handling; progression of granulation of Valencia Oranges; use of X-rays in citrus industry; sanitation in citrus packing houses.[7] Co-author of ASRE Application Data Sections 16-R, "Refrigeration of Oranges in California," and 18-R, "Refrigeration of Lemons and Grapefruit"; Chapter 14, 1946 Applications Volume, ASRE Data Books.

At present Manager, Field Laboratory, California Fruit Growers Exchange, Ontario, Calif.

HERMAN WILLIAM NIXON, Co-author Chapter 16. Born 7/3/89 in St. Paris, Ohio. Educated at University of Redlands, AB, 1916. Formerly, Instructor, grade and high schools, St. Paris, Ohio, 1909–12; packing house foreman, Leffingwell Ranch, Whittier, Calif., 1918–20; local inspector, California Fruit Growers Exchange, 1920–27; supervisor, 1927 to date.

Co-author Chapter 14, 1946 Applications Volume, ASRE Data Books. Author of many trade bulletins to California Fruit Growers Exchange member associations, pertaining to improvement in lemon handling practices.

Secretary-Treasurer, The Lemon Men's Club, 1940; Honorary Member, 1949.

At present, Supervisor Lemon Inspection, Field Service Department, California Fruit Growers Exchange, Los Angeles, Calif.

ROBERT D. NEDVIDEK (deceased), Co-author Chapter 16. Born 3/17/93 in Coon Valley, Wis. Educated at Pomona College, 1924. Formerly, Assistant Chemist, Research Department, California Fruit Growers Exchange, 1924–27; Research Chemist, 1927–49.

Co-author of "The Isolation and Distribution of Nitrogen in Dilute Alkali-Soluble Proteins of Healthy Valencia and Washington Navel Orange Fruits," *Jour. of Agricultural Res.*, 1/15/35; "Citrus Fruits," *Refrig. Eng.*, 4/46. Chapter 14, 1946 Applications Volume, ASRE Data Books; "Cleaning Citrus Fruit," 10/31 and "Coloring Citrus Fruit," 6/32, by Calif. Fruit Growers Exchange; number of articles for California Citrograph; and several U. S. patents.

Member, Amer. Chemical Society, 1925–30.

* This discussion applies specifically to California and Arizona citrus fruit. In general it applies likewise to that from Florida and Texas. However, there are some problems connected with the latter which require special treatment, and the reader should consult competent authorities in the various states such as the State Agricultural Experiment Station or the U. S. Department of Agriculture for detailed information.

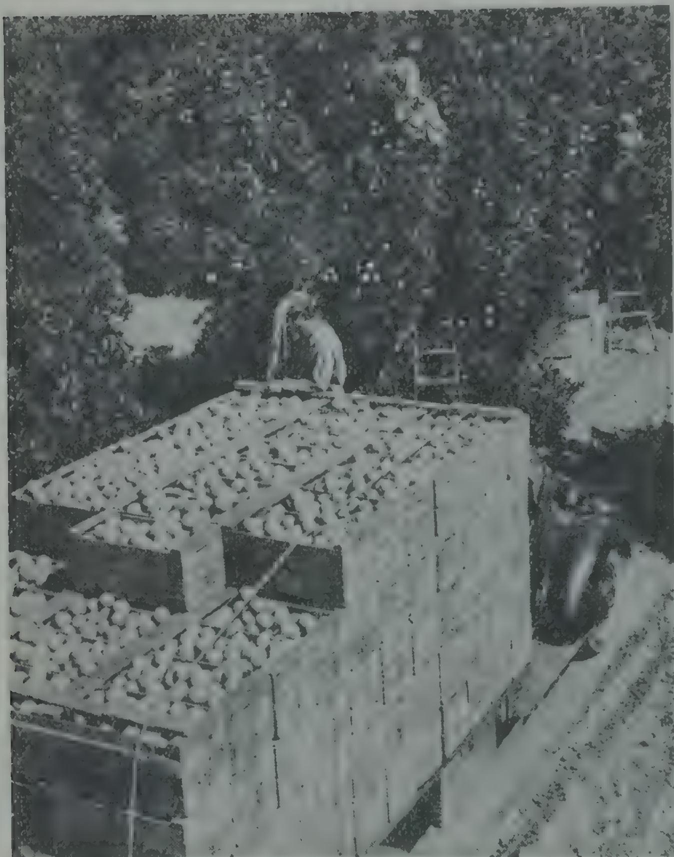

Fig. 1. Harvesting Scene in a California Orange Grove. Pickers Working on Ladders and Boxes Being Loaded onto a Motor Truck.

of proper size. The rings are usually of nickeled steel with a smaller loop of the same material added to help in holding. They are held in the palm of the left hand, the middle finger being thrust through the supporting loop, and are tried on lemons that appear to be of proper size. If the lemon has grown to sufficient size so that the ring will not slip over, it is taken from the tree.

Packing-house handling. In the packing house, citrus fruits are prepared for shipment by a number of carefully directed operations which are varied to suit the variety or quality of the fruit and market requirements. The general aim is to keep deterioration and decay to the minimum and prepare the fruit in an attractive manner. Wherever necessary throughout the packing house, gloves are worn to protect the fruit. All parts of the packing house are kept clean and sanitary. Mold spores and wet rots are not allowed to contaminate work room floors, storage rooms, or equipment; and all decaying fruit is hauled promptly to a disposal point far removed from the packing house.

After the fruit is received at the packing house, it is washed by means of a **mechanical washer.** Each washer is provided with a soaking tank from 20 to 30 ft long through which the fruit is floated before passing into the washer itself. All decay that has developed in the field boxes since picking is removed before the fruit enters the soaking tank. Some tanks have submergers 10 to 15 ft long to immerse the fruit during the soaking period. It has been found that complete immersion is necessary both to facilitate cleaning and to give the maximum mold control treatment. A solution of soap for cleaning purposes, and usually also a mold retardant to control decay, are used in these tanks. Sometimes a separate tank immediately following the washer is used for the mold control treatment. If fruit is smudge-stained due to orchard heating, kerosene or a solvent emulsion is added. A wash water temperature from 115 to 120 F is maintained to assist in cleaning and to aid in the control of many diseases, particularly brown rot. To avoid liberating oil from the rind and causing green-spotting and decay, it is usually necessary to hold lemons on the packing house floor for 24 to 72 hr prior to washing. The washer itself is generally constructed with cylindrical brushes, arranged horizontally in a series. These revolve rapidly and the fruit is conveyed onto them and brushed in a solution pumped from the soaking tank. A fresh water rinse, preferably warm, is applied both after washing and after treating.

Oranges, after washing, are dried by mechanical equipment which includes a series of **propeller fans** which move large volumes of air over the fruit. When dried, the fruit is polished and waxed, and then

ıssed immediately to the grading table. fter grading, it is conveyed to sizing ıuipment which separates the oranges ıto the standard sizes and drops them into ins for packing.

Grapefruit, after washing, may be packed ver standard orange equipment and ıipped immediately or stored for later ıipment. To retard deterioration and the ıte of shrinkage, a water wax emulsion is sually applied to grapefruit after washing, it is to be stored.

Lemons, after washing, are conveyed to sorting table for color separation. This accomplished by selecting the lemons of ach color desired and putting them loose nto the packing cases in which they are to e stored for curing. Usually four colors are ecognized and are designated as dark reen, light green, silver, and yellow. The lark green is a full green; the light green, partially colored green (a green with color vell "broken"); the silver, fully colored vith a green "tip" (stylar end); the yellow, ully colored and mature with no green showing. This segregation is to determine quality, color of the fruit being the most practical distinguishing mark. The dark green has the longest keeping properties, and after curing the best juice value. The yellow has poor keeping properties and is often marked by serious defects. Dark green has a normal storage life of from four to six months; light green, two to four months; silver, one to two months; and yellow, three to four weeks. These periods are approximate, as keeping quality of fruit varies considerably with season and grove. As with grapefruit, a light concentration of water wax emulsion is sometimes applied to lemons before they are put into storage. Following washing, lemons and grapefruit are allowed to dry off in storage.

Sizers have been added to lemon washer equipment, whereby the fruit, after washing, can be separated into three or more sizes before passing to the sorting tables for color separation. The separation of lemons into sizes and grades, as well as colors, at the washer aids in the filling of orders and facilitates the elimination of certain lots of undesirable sizes and grades for shipment to by-product plants.

Directly after washing and separation by color, lemons, loose in packing cases, are conducted to the storage rooms by belt conveyor or elevator. Except where natural climatic conditions are usually favorable to maintaining satisfactory storage, lemon packing houses generally maintain optimum conditions by well designed air conditioning and refrigeration equipment. Lemon storage will be more fully discussed in another section of this chapter.

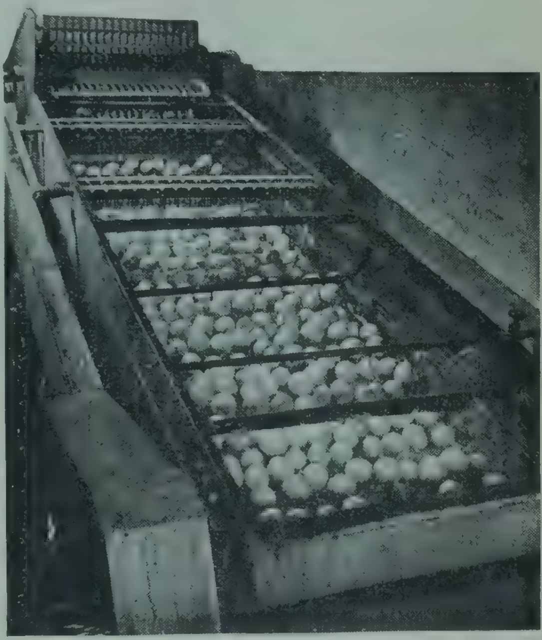

Fig. 2. Washing Oranges. Shows Spraying of Soaking Tank Solution Over the Brushes. A Similar Washer is Used for Lemons.

After storage, lemons are graded and then sized and made accessible to packers by means of a system of sizers and revolving circular bins or by a series of wide conveying belts. They are sometimes waxed just before they are graded and packed. Figs. 1, 2, and 3 are typical scenes in the California citrus areas.

Grading is usually accomplished by removing the lower grades from the first grade, allowing the higher grade to move forward without handling to the packing equipment. Sometimes "check-graders" are used to aid in maintaining a uniformly satisfactory grade. The grading operation is particularly important as it is the final classification of the fruit before shipment. Sound judgment and unusual care are required to determine the proper grading of each lot, because of wide varia-

Fig. 3. In the Foreground, Packing Lemons from Large Rotary Bins. In the Background, Grading Lemons.

tions in the quality of fruit from different groves. When lemons and grapefruit are taken out of storage for grading and shipment, fruit that has decayed is removed, and in addition all sound fruits touching decayed ones are discarded because they may be infected. Sound lemons touching spoiled ones and known as "contacts" are usually sent directly to a by-product plant.

The diseases most commonly seen in lemons and grapefruit after storage are green mold, blue contact mold, brown rot, sour rot, grey mold, cottony rot, Alternaria rot, and Trichoderma rot.[1]

In addition to decay there are a number of other defects that have to be considered in grading the fruit. Each blemish is judged and the fruit affected placed in its proper grade according to the nature of the defect or as grade rules specify. Constant inspection by cutting is necessary to determine the internal quality of each lot, and often tests are made by cutting a sample of the fruit before or after grading to determine the exact percentage of "off-grade" fruit present and, therefore, the brand under which such fruit should be shipped. The segregation of frost damaged fruit and granulation of Valencia oranges are often accomplished by fluoroscopic examination.

It is standard practice in California to wrap citrus fruit in oil treated tissue wraps of appropriate colors and printed with attractive designs. The wrap is considered essential because it furnishes protection to the fruit against abrasion, spread of mold spores, contamination by dust and dirt in transit and during distribution in the market, and against excessive shrinkage.

After wrapping, the fruit is placed by size and count in rigid wooden boxes that have been standardized by law. Each box bears a lithographed label giving the brand name together with the name and address of the shipper and, in case of oranges and grapefruit, the name of the variety. Special trade-marks sometimes appear on the label. Boxes are numbered by the packer for identification and stamped by the pressman with the count and average diameter indicating the size, as required by law. The pressman also puts on a lid and metal strap over the center by means of a mechanical press.

After being lidded, the completed pack-

ages are loaded into standard refrigerator cars for transportation to market. Boxes are loaded on end with label up and sides of boxes toward the ends of the car, bottoms or tops facing the car sides.

Accelerated Coloring or "Sweating"

Two varieties of oranges, Washington Navel and Valencia, constitute the major portion of the California crop. The harvesting of each variety requires approximately six months, but since the Navels mature in November and Valencias in May, fresh oranges are available throughout the entire year. Grapefruit from the desert areas of California and Arizona is available for seven to eight months of the year and grapefruit from central and southern California is available for the remainder of the time.

All varieties of citrus fruit must be mature before they are picked.[2] Color is not always a criterion of maturity. The natural change of color in oranges from dark green to deep orange is a gradual process while the fruit remains on the tree, the fruit remaining dark green from its formation to the time it is nearly full size and approaching maturity, when a stage is reached where the color changes may become very rapid. The color change is influenced greatly by temperature variations. A few cold nights followed by warm days may completely color oranges that were previously very green. The color changes in lemons and grapefruit are similar, except that the final color is yellow. Unfavorable weather conditions may delay coloring even after the fruit is fully mature.

Up to a certain point, the natural color changes in the Valencia orange follow the trend described, but complete or nearly complete orange color generally develops some time before the fruit is mature and green color may return after the fruit has reached its prime. Navel oranges and grapefruit harvested in early winter may be mature and of good eating quality although the rind is green in color. At certain times of the year only lemons green in color, although otherwise mature, are available for market. Since the consumer demands fruit of characteristic color, it is sometimes necessary to put the fruit through a coloring or "sweating" process. Special rooms are provided for this purpose.

Fig. 4 shows the arrangement of a "sweat-room" equipped with an evaporative cooling unit suspended from the ceiling. These units may also be equipped with an electric or steam coil for heating during cold weather. Air is circulated continuously to maintain a uniform temperature of 65 to 70 F during the sweating operation. One part of ethylene in 50,000 to 200,000 parts of air, the concentration depending upon the variety and the intensity of green pigment in the rind, is maintained in the sweat-rooms. During this operation fresh air is introduced into the room, and a relative humidity of 88 to 90 percent is maintained. To avoid excessive deterioration of the fruit during the sweating operation, it must be carefully done by trained personnel.

Oranges and grapefruit that require this treatment are placed in the sweat-rooms as soon as delivered to the packing house. Lemons are first washed and separated into color classifications according to their degree of maturity or color before being put into the sweat-rooms.

Lemon Storing

A large portion of the lemon crop is picked during the period of least consumption and must be held in storage until consumer demand justifies shipment.

To withstand transportation and different climatic conditions at distant sales points, lemons must first be properly conditioned or **cured**; consequently during the holding period, they must be stored under the most favorable conditions.

Since there are only a few days in each year when natural atmospheric conditions are favorable to the ideal storage of lemons, air conditioning is quite generally used.

In air conditioning lemon storage rooms, there are four major factors involved: temperature control, relative humidity control, cleaning the air and ventilation, and circulation or distribution of the air. All are important to a well-balanced system and the value of each is discussed to show its importance.

1. Uniform temperature control. The maintenance of a uniform temperature of

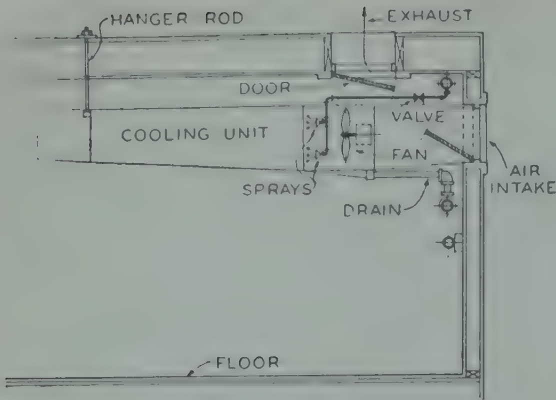

Fig. 4. Sweat Room Showing Evaporative Cooling Unit in Position.

58 F is of great importance. As in the groves, fluctuating or low temperatures in storage rooms cause lemons to develop an undesirable higher color or bronzing of the rind. Temperatures of 52 F and lower cause a staining or darkening of the membranes dividing the segments of the edible pulp and may affect the flavor. Temperatures above 60 F shorten the storage life and are more favorable to the growth of decay-producing organisms.

To maintain uniform temperatures in lemon storage rooms during winter and summer, it is necessary to have **both refrigeration** and **heat.** When outside atmospheric temperature is too low, it is best not to introduce fresh air unless it can be properly conditioned.

Proper **stacking** of the fruit in storage rooms is important to secure uniform air circulation and temperature control. There should be not less than 2 in. between stacks, 4 in. between rows, and at intervals there should be trucking aisles at least 6 ft wide. **Fig. 5** shows a typical stacking arrangement.

2. Control of relative humidity. In some sections of California, a relative humidity of 86 to 88 percent is usually ideal, while in other sections lower relative humidity would be more nearly ideal for curing the rind. The desirable relative humidity may also vary with the season, vitality of the fruit, and previous outside weather conditions. Unless normal shrinkage and curing of the rind are accomplished in the storage rooms, they will occur rapidly in transit to market, and loose, unsightly appearing packages will be delivered to the buyers. Excessive moisture content in the air of storage rooms does not permit proper curing and favors the growth of molds on the fruit and on the wood of storage boxes.

The **air washer,** because of its utility and efficiency, is essential. The velocity of air should not exceed 500 ft per min through the free area. A spray chamber with two banks of spray nozzles opposing each other produces fine spray under higher water pressure. This is desirable for air cleaning and high humidity control. Sufficient area and capacity to take full advantage of low outside wet bulb conditions are an operating economy to the owner.

All air conditioning systems for lemon storage should be equipped with **both preheating** and **reheating devices** to maintain uniform conditions in storage, regardless of the conditions outside.

3. Air cleaning and ventilation. Lemons give off **carbon dioxide** and other products and take up oxygen during storage. The oxygen used must be replaced in the storage rooms and the respiration products removed. Besides carbon dioxide, the respiration products, under certain conditions,

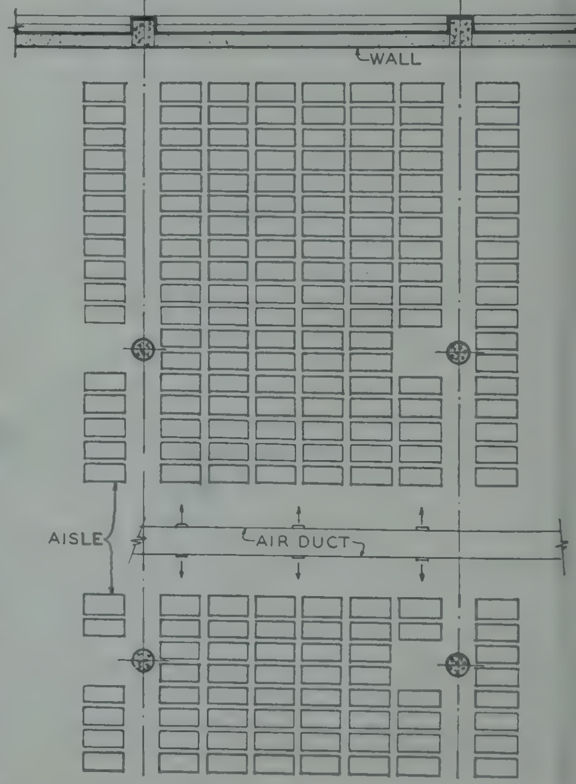

Fig. 5. Typical Stacking Arrangement for Lemons and Grapefruit.

may contain acetaldehyde.[3] Certain molds growing on lemons produce a gas believed to be ethylene.[4] Since **ethylene** has a marked tendency to stimulate respiration of the fruit, it too must be removed from storage atmosphere. Until other dependable methods are developed, this must be done by ventilation. In order to determine ventilation requirements, the carbon dioxide content of the storage atmosphere can be taken as an index of the harmful respiration gases. While this test is only fairly accurate for determining the accumulation of ethylene or other harmful products, it is the simplest and most reliable method now known. The carbon dioxide content should not be allowed to exceed 0.1 percent.

The **fresh air** requirements may vary. Fruit which has been injured by cold weather or extreme heat has a higher respiration rate than normal. Fruit of different degrees of maturity and vitality may also have different respiration rates.

Table 1 shows the respiration rate of lemons and the production of sensible heat.

For normal fruit it is good practice to design for 75 cu ft per min of fresh air per carload (650 storage boxes).

Table 1. Average Respiration Rates of Storage Lemons

Temperature, F	Mg. CO_2,[a] per kg per hr	Sensible heat,[b] Btu per ton per 24 hr
32	2.65	580
40	3.70	810
50	10.50	2310
60	13.5	2970
70	18.6	4090
80	28.2	6200

[a] Haller, et al. Respiration of Some Fruits in Relation to Temperature. Proc. Amer. Soc. Hort. Sci. 1931.
[b] Calculated from mg CO_2 per kg of material per hour ×factor 220.

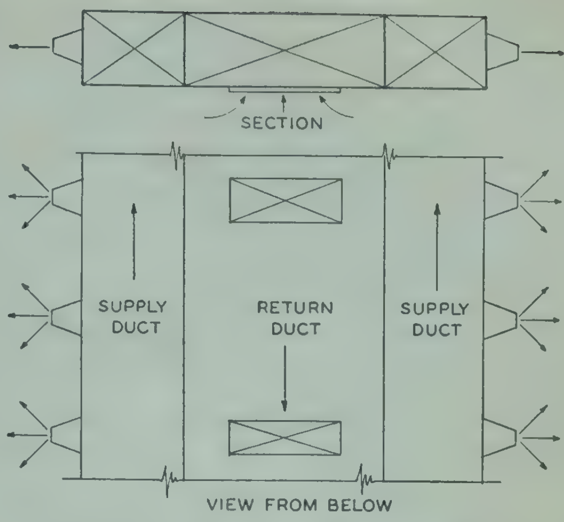

Fig. 6. Supply and Return Air Ducts.

4. Air distribution. Without an adequate volume of air uniformly distributed it is not possible to maintain favorable conditions in lemon storage rooms. Air distribution should be accomplished with well designed supply and return **ducts,** and the air should be delivered as close to the fruit as is possible. The **volume of primary air circulated** should not be less than 1 cu ft per min per storage box, and it should not be forced to travel more than 35 ft from the nozzle. No attempt should be made to substitute secondary air circulation and auxiliary atomizing spray nozzles for an adequate supply of primary air in lemon storage rooms. The velocity of air through the ducts and air nozzles should not exceed 1200 ft per min. Higher velocity air ejector nozzles complicate the control of storage conditions. **Fig. 6** shows the preferred duct design.

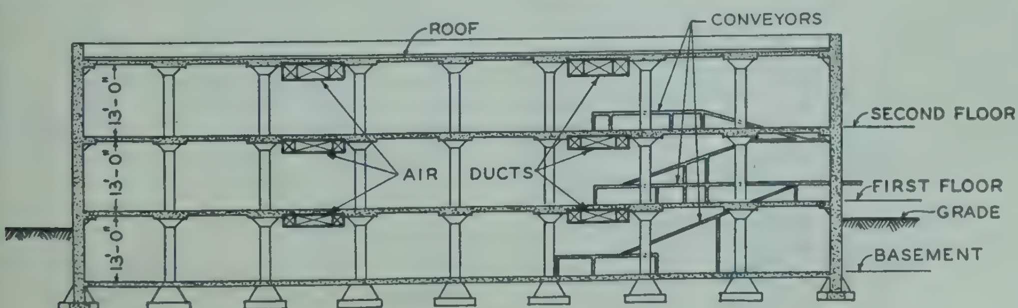

Fig. 7. Cross Section Typical Well Constructed Lemon or Grapefruit Storage Plant, Adjacent to Packing House.

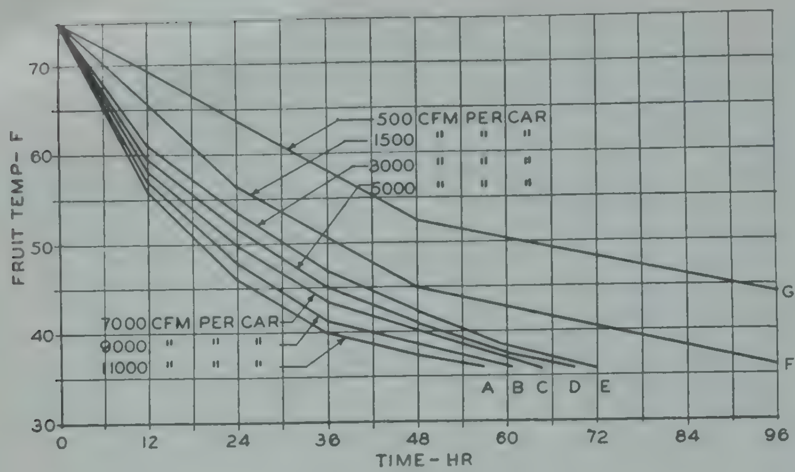

Fig. 8. Rate of Precooling with Various Volumes of Air. Temperature of Air Entering Precooling Room, 34 F.

Air conditioning equipment must be automatically controlled. The design and flexibility of the **control system** must be such that varying conditions may be easily obtained. For all citrus storage, pneumatic or electrical controls, because of their operating efficiency, are desirable.

In all building construction and especially in storage rooms with refrigeration and air conditioning, good engineering is the least expensive service that can be purchased, but designing a satisfactory system of air conditioning for lemons requires a knowledge of the fruit itself, a fact not always recognized by the air conditioning industry. **Fig. 7** shows a cross section of a typical well designed and well constructed lemon or grapefruit storage plant.

Grapefruit Storage

In California grapefruit is not stored on a large scale. In Arizona it is stored under approximately the same atmospheric conditions as are lemons in California, except that a temperature of 60 F is recommended. Grapefruit has a decided tendency to become highly colored or bronzed at temperatures below 60 F. Temperatures above 60 F speed deterioration.

It is desirable to apply a special **waxy coating** to the fruit before it is put into storage. With this waxy coating and adequate air conditioning, the grapefruit may be satisfactorily stored for as long as three months.

Since the flavor of grapefruit is delicately balanced and difficult to sustain, fresh air requirements must be maintained at all times, and the **storage temperature** must not be allowed to fluctuate more than ±1 F. As with lemons the carbon dioxide content of the storage atmosphere should not exceed 0.1 percent.

The respiration rate of grapefruit varies considerably, the average rate being near the rate of a tree-ripe lemon. **Table 2** gives data on the rate of respiration and the production of heat for Florida grapefruit per ton per 24 hr.

The respiration rate of Arizona and California desert grapefruit is very close to that shown in the above table.

Grapefruit of low acidity, less than one percent anhydrous citric acid, is not considered of good storage quality. When the **acid content** goes to .5 percent the fruit should be shipped to market at once or disposed of through other channels.

Table 2. Average Respiration Rate of Grapefruit and Production of Heat

Temperature, F	Mg. CO_2,[a] per kg per hr	Sensible heat,[b] Btu per ton per 24 hr
40	4.86	1070
50	6.92	1522
60	12.60	2770
70	16.0	3520
80	19.0	4180

[a] Haller, et al. Respiration of Some Fruits in Relation to Temperature. Proc. Amer. Soc. Hort. Sci., 1931.
[b] Calculated from mg CO_2 per kg of material × factor 220.

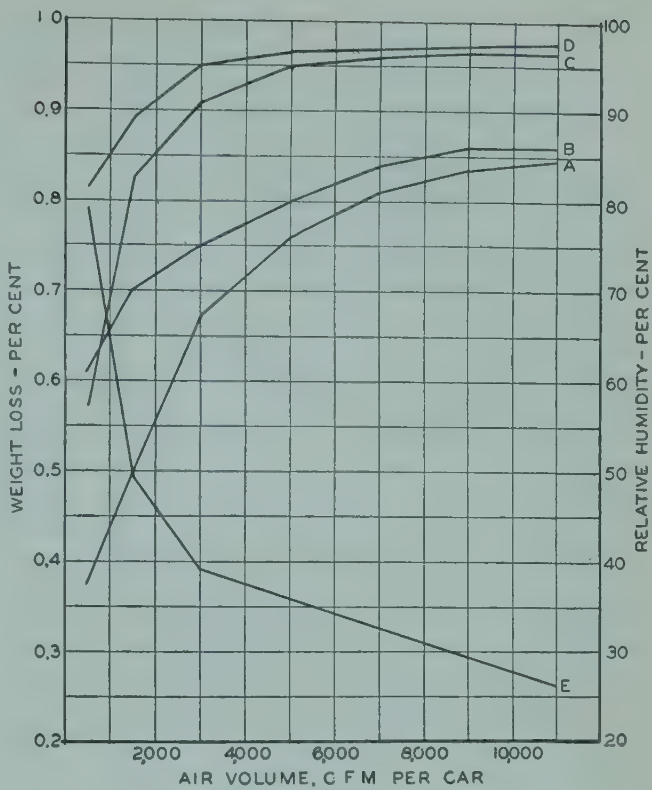

Fig. 9. Effect of Air Volume on the Relative Humidity, and Weight Loss During 4 Days Precooling. Temperature of Supply Air Entering the Room, 34 F.

A = Calculated relative humidity during the first hour of precooling.

B = Observed humidity during the first hour of precooling.

C = Calculated humidity at the time the fruit temperature reached the precooling temperature.

D = Observed humidity at the end of the precooling period.

E = Observed weight loss at the end of 4 days.

Table 3.* Approximate Evolution of Heat by California Oranges Stored at the Temperatures Indicated

Temperature, F	Heat evolved per ton of fruit, Btu per 24 hr
32	900
40	1400
60	5000
80	8000

* Dean H. Rose, R. C. Wright and T. M. Whiteman. Commercial Storage of Fruits, Vegetables, and Florists Stocks. U.S.D.A., Circular No. 278. 1933.

Investigators have searched with limited success for a method of determining the storage life of citrus fruits. The anhydrous citric acid content can be determined quite easily and is regarded as a fair indicator of the storage life of grapefruit.

Recommended storage conditions for lemons and grapefruit are as follows:

	Lemons	*Grapefruit*
Temperature, F	58	60
Relative humidity, percent	84–88	86–88

Refrigeration of California Navel and Valencia Oranges

Decay, aging, pitting, and other rind defects in oranges are accelerated at warm temperatures and are reduced by precooling and refrigerated transportation. Temperature, however, is not the only factor; condition and variety of fruit, type of package, humidity, and ventilation are also of great importance. Often maladjustment of one or more of these factors can nullify the otherwise beneficial results of refrigeration.

The rate of respiration of citrus fruit is normally much lower than that of most stone fruits and green vegetables, and somewhat lower than that of apples. Besides temperature the strongest influence on the respiration rate of citrus fruits is the presence of ethylene. Navel oranges have the highest respiration, followed by Valencias, grapefruit, and lemons. Table 3 shows the heat generated by the fruit through respiration.

Experience has definitely established

that if the carbon dioxide content of storage rooms is held at approximately 0.1 percent or below, a sufficient volume of fresh air is being supplied.

Precooling of Packed California Oranges

The term "precooling" as applied to oranges means the process of removing rapidly the initial heat of the fruit immediately after it has been processed and packed for shipment, so that lower and more uniform temperatures will be maintained in transit without excessive consumption of ice. One advantage of precooling oranges is that some form of modified refrigeration may be used in transit to replace the more expensive standard refrigeration.*[,5]

Precooling plants are usually rated upon the number of cars of fruit that they can precool per day during continuous operation. In addition to precooling the average number of cars of oranges packed per day, a precooling plant should have **storage capacity** for at least ten days' supply of fruit. There are several types of precoolers in general use, the basic difference being in the number of rooms and the method of cooling and circulating the air. Their efficiency is dependent on meeting the following conditions:

- Air volume per car during precooling; not less than 3000 cu ft per min.
- Relative humidity of supply air; 95 percent or above.
- Temperature of supply air entering room; not more than 2 F below the selected precooling temperature, which may range from 35 to 37 F.
- Ventilation; sufficient fresh air to keep carbon dioxide content below 0.1 percent (approximately 10 cu ft per min per car).

The **rate of precooling** is governed by the initial fruit temperature (assuming adequate refrigeration equipment is provided), and the temperature, volume, and uniform distribution of supply air. **Fig. 8** shows the precooling rates with varying air volumes, the temperature of the supply air entering the precooler rooms being the same (34 F) for all air volumes. Naturally the rates of precooling can be equalized by lowering the temperature of the supply air, but not without damaging the fruit. **Table 4** shows the weight losses and severe rind defects, including decay, that developed during four days in the precooler under the conditions given in Fig. 8.

Oranges precooled with air volumes above 1500 cu ft per min per car, arrive on the market in better condition than warm fruit loaded directly into preiced refrigerator cars and shipped under standard refrigeration. The beneficial results derived by precooling diminish as the air volume is reduced, and actual damage to the fruit occurs as the volume decreases below 1500 cu ft per min per car.

The **relative humidity** of the air in the rooms during precooling has a direct relation to the weight loss and severe rind defects. Humidity is just as important as temperature in preventing grade and quality deterioration of oranges during precooling and shipment to the market. A high relative humidity can be maintained in precooler rooms without resorting to the use of auxiliary sprays and complicated controls, simply by using a sufficient air volume and the brine spray system. **Fig. 9** shows the weight loss during four days precooling with different air volumes; the ob-

Table 4. Percentages of Severe Rind Defects and Decay Developed during Four Days Precooling and 10 Days Storage under Conditions of Standard Refrigeration with Varying Amounts of Air—Supply Air Temperature, 34 F

Air volume, cfm per car	Percentage of severe rind defects+decay	Percentage of weight loss
11,000	1.48	0.26
3,000	1.84	0.39
1,500	2.04	0.48
500	3.09	0.79
**Check, not Precooled	2.08	0.50

** 14 days storage under conditions of standard refrigeration.

* Standard Refrigeration—The reicing of the refrigerator cars in transit at all regular icing stations.

served humidities for the first hour of precooling and at the end of four days precooling; and the calculated humidities during the first hours of precooling and at the end of the precooling period. The results as given for the calculated humidities during the first hour were derived from the actual precooling rate for the same period of time.

The **design and construction** of a building for precooling and storage determines the operating practice and conditions that can be maintained. It is important to coordinate the engineering of the building with that of the refrigeration and air distribution system before construction of either is started.

Fig. 10 shows the arrangement of air ducts, brine spray and general floor plan for a typical precooling and storage plant. The air ducts and brine spray chamber are of sufficient size to reduce friction losses to a minimum. The brine spray chamber is long enough to insure efficient heat transfer. The air as it is being recirculated makes a minimum number of right angle turns. All the air ducts and brine spray chamber extend the full height of the building. The dampers, both supply and exhaust in each individual room, are operated simultaneously, thereby simplifying air volume control.

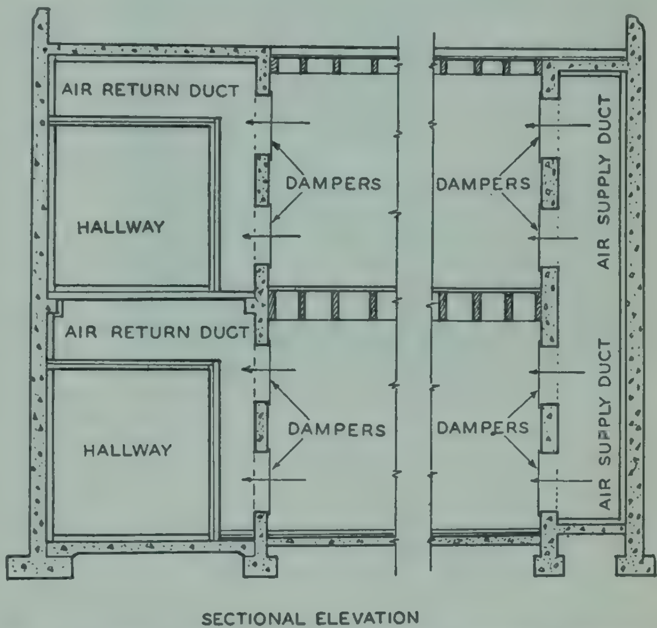

Fig. 10. Typical Precooler and Storage Rooms for Oranges.

Precooling may also be accomplished in the refrigerator car after it has been loaded. There are three different methods of **car precooling,** one by means of portable fans installed at the top opening of the bunker at each end of the car, using salt and ice in the bunker as a source of refrigeration. The second method has stationary or portable refrigerating units, which force low temperature air into the car and around the fruit. The third and the most satisfactory method is to precool the fruit in the cars in transit, by means of stationary fans permanently located under the floor racks at both ends of the refrigerator car. The fans, which are operated from the wheels of the car, deliver the air to the bottom of the ice bunkers, then up through the ice in the bunkers and out at the top opening of the bunker. The fans are operated mechanically when the car is in motion or by electric motor during stationary precooling (Fig. 11). According to Mann,[6] "in fan-equipped cars it was possible to obtain as good refrigeration for a 693-(three layers high) box load as for a 462-(two layers high) box load without fans." **Fig. 13** shows the precooling rate during 10 hr. precooling for three different methods of precooling fruit in refrigerator cars prior to shipping (462-box load, two layers high).

Storage of packed California oranges. Cold storage (35–37 F) at shipping point should be used only to keep an adequate supply of fruit on hand to carry over short periods of adverse weather conditions that hamper harvesting operations and otherwise would interfere with shipping schedules. Under ordinary circumstances several days' supply is sufficient. **Long storage is never desirable** as the consumers prefer fresh oranges whatever the geographic origin.

In contrast to many other fruits, oranges

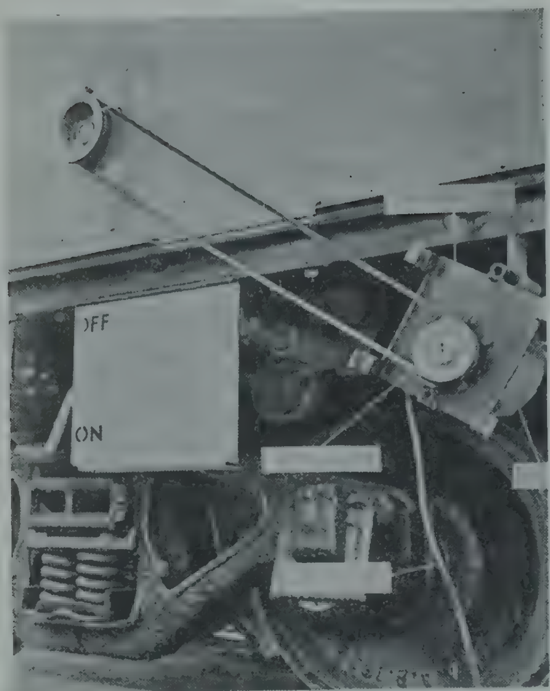

Fig. 11. Motor in Place for Precooling in Fan Equipped Refrigerator Cars.

Note drive which is dropped onto wheel to turn fans when car is in motion.

have a long harvesting season, and a moderately long life after picking, which can be extended somewhat by low-temperature storage. However, California oranges ordinarily deteriorate faster in storage than if left on the tree under normal weather conditions, as shown by **Fig. 14.** Under some conditions granulation, or hardening of the juice sacs, may also increase more rapidly in storage than on the tree.

The effect of storage on juice quality is variable. The ability of any individual lot of fruit to retain its original fresh flavor depends to a large extent upon its original acidity. The juice quality is closely associated with the ratio of total soluble solids to acid. As the acid decreases the juice tastes sweeter and eventually becomes flat and insipid. Fruit of low initial acidity may not lose any more acid than one with high acidity but the change in flavor will be much greater. Slightly off, or stale flavors are also more readily detected in juices of low acidity.

During storage or shipment under the most favorable conditions the juice content of oranges decreases at the rate of about one percent per week. Under less favorable conditions which have a tendency to increase the rates of respiration and transpiration, the nutritional loss will be greater.

After they have been packed, oranges are transferred to the precooling or storage rooms by means of a power driven belt conveyor. Here the packed boxes are stacked three or four high on end in rows parallel to, and with the crown or bulge of the packed box at right angles to the direction of the air flow, to permit free air circulation around the stacks of fruit.

Stacking or unloading fruit in the precooling or storage rooms is by far the most arduous task in the packing house. Under favorable working conditions each man often handles between 40 and 50 tons of fruit per day. Whenever it is necessary to space the stacks of fruit or carry it from the

Fig. 12. Interior of a Precooler or Storage Room for Oranges.

conveyer for a great distance, more men are required. Unless the crown or bulge of the packed boxes faces the conveyor, space must be provided between the individual stacks, to avoid breaking the straps or lids during the unloading of the room. **Fig. 12** shows the most efficient method of stacking fruit in a typical precooler or storage room.

After the room has been filled, the fruit is cooled rapidly to the desired storage temperature, after which the air volume is reduced to approximately 1200 cu ft per min per car, and held at this value until the fruit is removed from the room. The temperature of the supply air entering the room should be not more than 2 F below the selected storage temperature of the fruit.

Recommended conditions for storage of packed oranges

*Minimum air volume per car (during precooling), cu ft per min	3000
Minimum air volume per car after fruit temperature reaches storage temperature, cu ft per min	1200

* Total volume of supply air entering the storage room, not to be confused with secondary or induced air circulation resulting from air low in temperature and volume supplied at high velocities.

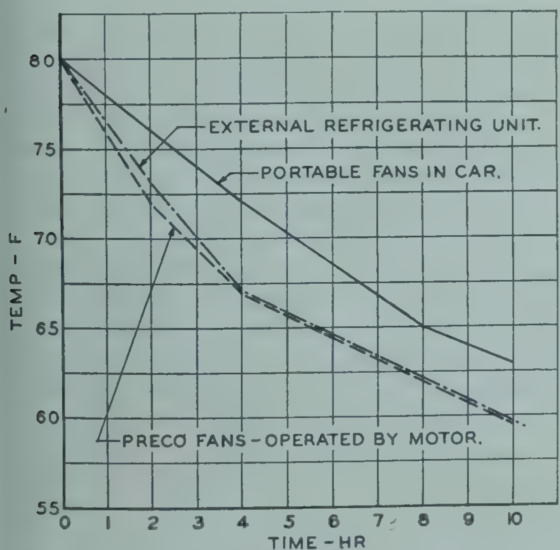

Fig. 13. Rate of Precooling Oranges in Refrigerator Cars (462-Box Load).

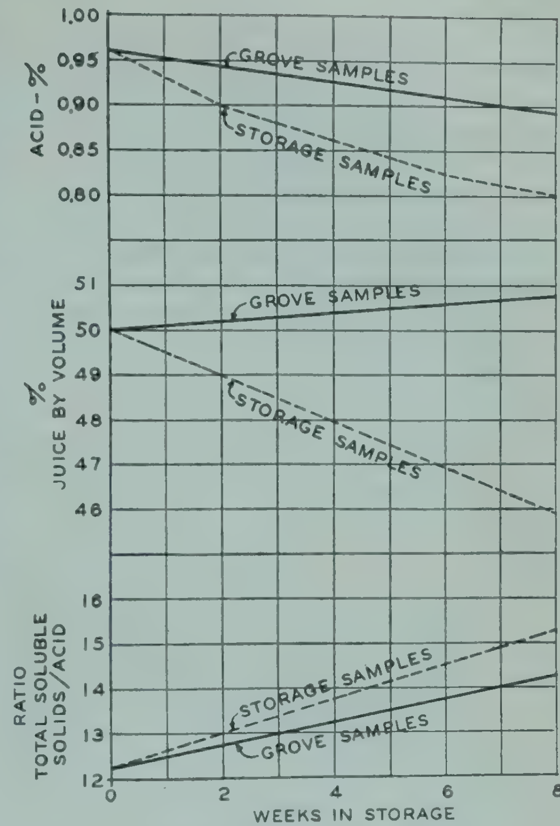

Fig. 14. Change in Citric Acid, Juice Content and Ratio of Total Soluble Solid to Acid for Oranges During Low-Temperature Storage and on the Tree.

Fruit temperature, F	36
Supply air temperature entering room, F	34
Fresh air—approximately, cu ft per min per car,	10
Relative humidity of supply air—minimum, %	95

Since the bulk of the California orange crop is sold in distant markets the **transportation problem** is similar to that encountered in refrigerated storage. All other factors being equal, the deterioration in grade and quality in transit is limited by the length of time in transit, type of refrigeration and rate of cooling. The length of time required to reduce the temperature to a point below 45 F has a direct bearing on grade deterioration in transit. The minimum weight and grade losses occur when the fruit is first precooled to 35–37 F and then loaded into **preiced cars** which are replenished at the first icing station and

reiced at least once in transit. Similar results may be accomplished by loading the fruit directly into preiced fan-equipped cars, reicing at the first icing station and then daily for the next two days.

Factors limiting the storage life of packed oranges. The maximum time that packed California oranges can be held in storage and ultimately give consumer satisfaction in any market in the United States or Canada is affected by the factors listed below.

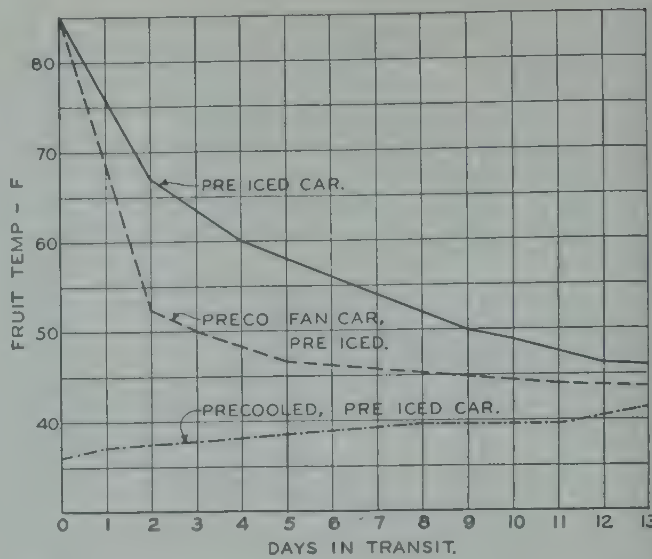

Fig. 15. Temperature of Packed Oranges in Transit under Three Different Methods of Refrigeration.

Preiced car. Replenish—do not reice.
Preco Fan car—preiced car. Replenish—do not reice.
Precooled—preiced car. Replenish—do not reice.

A. Factors originating prior to storage.
1. Climatic and environmental
2. Cultural and pest control
3. Degree of maturity
4. Picking under adverse weather conditions
5. Care in handling under all conditions
6. Ethylene treatment
7. Cleanliness of the packing house
8. Other packing house operations such as cleaning, treating, waxing, grading, etc.

B. Factors originating during storage.
1. Air volume during precooling and storage
2. Temperature and relative humidity of supply air
3. Uniformity of air circulation
4. Ventilation.

C. Factors originating in transit.
1. Type of refrigeration
2. Length of time in transit.

D. Factors originating on the market.
1. Storage conditions while fruit is in the hands of the jobber and retailer
2. Time required to dispose of the fruit to the ultimate consumer.

A few of these factors will be discussed briefly to emphasize the importance of a thorough knowledge of all phases of handling and treating the fruit from the grove to the market.

Fig. 16 shows the effect of storage temperature and degree of maturity on the keeping quality of packed oranges. As the storage temperature is increased (minimum air volume, 3000 cu ft per min per car), there is a corresponding increase in all **rind defects** (pits, spots, age, etc.), and decay. Also as the maturity of the fruit increases, it becomes more susceptible to injuries, rind breakdown, and decay. **Fig. 17** shows the effect of air volume (other factors being equal) on the development of rind defects, and decay, and the loss in weight. As the air volume increases the weight loss and all rind defects and decay decrease. As much actual damage to the fruit results from two weeks' storage in rooms using 750 cu ft per min per car plus two weeks under standard refrigeration as in four weeks at the recommended storage conditions and the same shipping conditions of standard refrigeration.

Fig. 18 shows the effect of three factors, individually and collectively, on the development of rind defects, and decay, during storage. The results given here were derived from a large number of comparable lots of fruit. The **ethylene-treated fruit** was handled under the recommended method previously described. The untreated fruit was stored under comparable

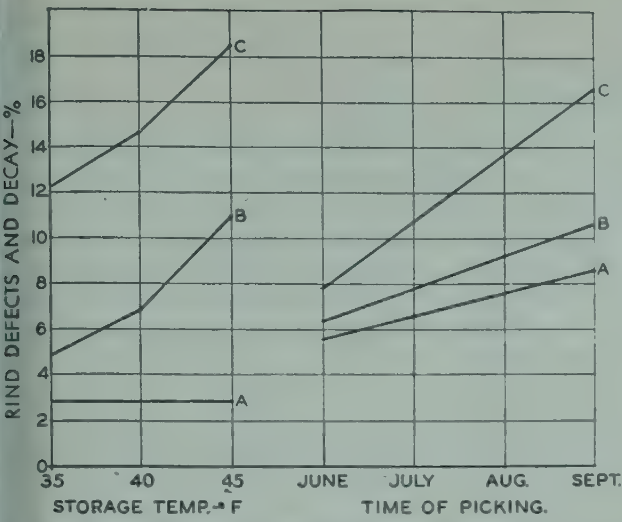

Fig. 16. The Effect of Storage Temperature and Degree of Maturity on the Development of Rind Defects and Decay, During Storage of California Valencia Oranges.

A. Two weeks under standard refrigeration.
B. Two weeks at indicated temperature (35 F, maturity effect) plus two weeks at standard.
C. Same as B except four weeks in storage room.

conditions of temperature and relative humidity for the same length of time. Both the treated and the untreated lots were packed and placed in the various storage rooms the same day, one half packed with wrappers and the other half without wrappers.

Fig. 19 shows the **seasonal variation** for Navel and Valencia oranges for a four-year period. The fruit was taken from the same groves on approximately the same picking dates each season.

The effect of each individual factor on the development of decay, severe rind defects and deterioration in eating quality is cumulative, and unless a sound policy is adopted in regard to picking and the selection of fruit used for storage, considerable loss may result. Visual inspection of the fruit at the time of removal from storage may indicate a sound condition, when in reality severe damage may have occurred, but the actual breakdown may not become apparent until the fruit reaches the market or is in the hands of the consumer.

The potential storage life of packed oranges varies according to the variety and the conditions previously mentioned. Normally, however, for fruit picked, handled and stored under the conditions recommended, this storage life is as follows (including the time in storage in California, in transit under refrigeration and the time during which it is in the hands of the various dealers before it reaches the ultimate consumer or, in other words, the total time from the orchard to the consumer):

Navel Oranges	*Ethylene treated*	*Untreated*
Early maturity to fully mature	6 weeks	8 weeks
Full, mature to over-ripe	4 weeks	5 weeks
Valencia Oranges		
Early maturity to fully mature	6 weeks	8 weeks
Fully mature to over-ripe	4 weeks	6 weeks

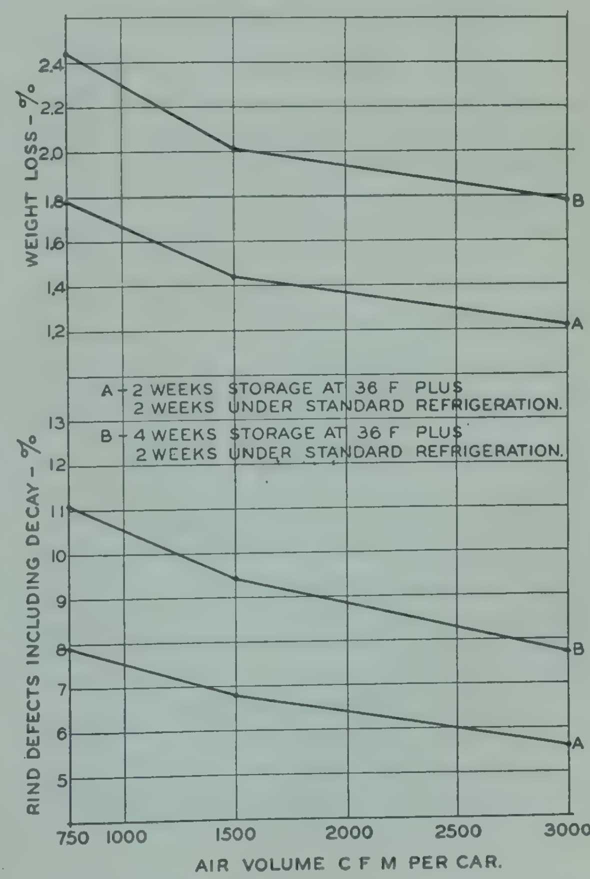

Fig. 17. The Effect of Air Volume During Storage of California Valencia Oranges, on the Loss in Weight and Development of Rind Defects and Decay.

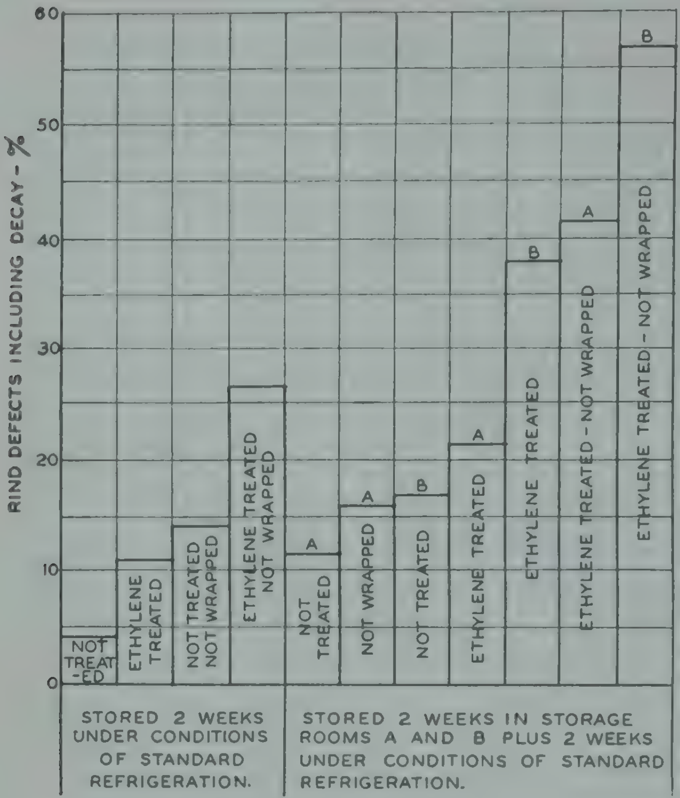

Fig. 18. Effect of One or More Individual Factors on the Development of Rind Defects and Decay, during Storage of California Valencia Oranges.

A. Recommended storage conditions.
B. Low air volume; storage room 500 cfm per car.

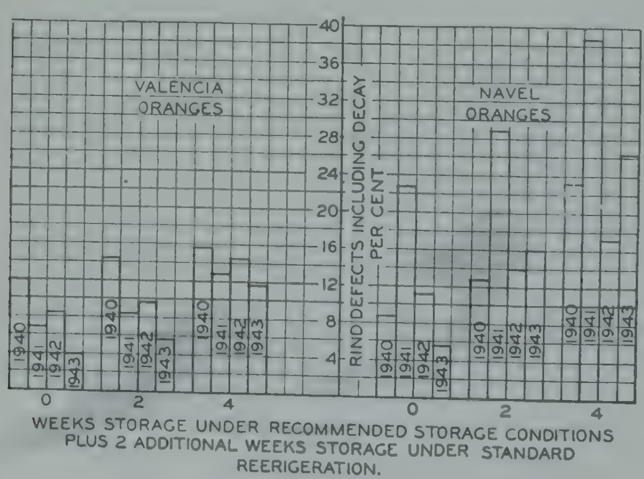

Fig. 19. Showing the Seasonal Variation of the Development of Rind Defects during Storage of California Valencia and Navel Oranges.

Considering all the factors that influence storage life, it becomes apparent that the maximum storage life is not always predictable unless all adverse factors can be recognized and taken into consideration. To give consumer satisfaction, California oranges, should have at least two additional weeks' storage life remaining when unloaded at the market.

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17. EGG STORAGE

THE annual production of eggs in the United States runs close to 4.5 billion dozens. These eggs, for the most part, come from the Middle Western states where small farm flocks predominate. Egg production with this type of flock is highly seasonal; over 40 percent of the yearly total occurs during the months of March, April, May and June. It is not surprising, therefore, that at least one-fifth of the eggs entering the large markets in this country during the year are stored (in the shell, frozen and dried).

SHELL EGGS

The use of **refrigeration** ranks highest of all controls which may be applied in the **preservation of quality** in shell eggs. Literally hundreds of methods for treating eggs have been devised for extending their edible life; none has surpassed the efficiency of low temperatures. Clean, sound eggs, properly packed, promptly cooled and kept at 29–31 F and 85 to 90 percent relative humidity in non-stagnant air retain their initial quality remarkably well for approximately six months.

Quality Factors

The following criteria need to be considered in determining egg quality:

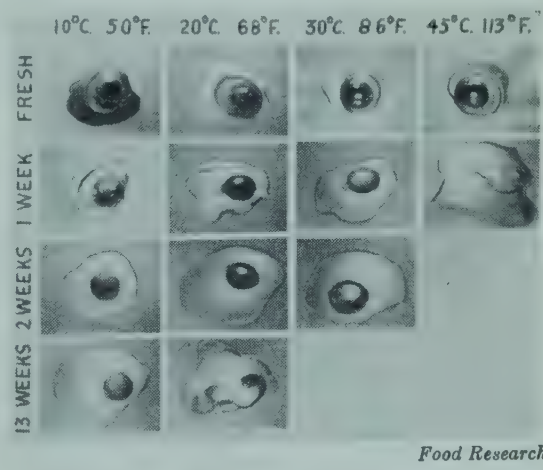
1. Odor and flavor
2. Appearance
3. Nutritive value
4. Culinary value
5. Microbiological condition.

Most consumers think of "fresh-egg" quality in terms of the first two factors listed above. An egg having a thick, gelatinous white completely surrounding an upstanding yolk of mild "egg" flavor is thought to be perfect. However, eggs have many other uses where the appearance and flavor do not count so heavily, e.g., custards, cakes, candies, etc. It is evident, therefore, that quality varies from use to use. Generally speaking, eggs used for poaching and frying must meet the most exacting tests of quality; those in cookery, the least exacting tests.

Quality Losses

Qualitatively there are three distinct kinds of deterioration in shell eggs: (a) changes brought about by **chemical reactions,** (b) decomposition by **bacteria and molds,** and (c) changes in flavor and odor brought about by **absorption of foreign substances.**

The change in **physical appearance** of eggs is easily observed. **Fig. 1** shows the effects of time and temperature on the



Food Research

Fig. 1. The Effects of Time and Temperature on Deterioration of Eggs.

GEORGE F. STEWART, Author Chapter 17. Born 2/22/08 in Mesa, Arizona. Educated at Phoenix Junior College, 1928; Univ. of Chicago, BS, 1930; Cornell University, PhD, 1933. Formerly, in charge of research and development pertaining to poultry and dairy products, Omaha Cold Storage Company, 1933–38; Research Associate Professor, Poultry Husbandry Dept., Iowa State College, 1938–42; Research Professor, 1942–48; Associate Director, Iowa Agric. Exp. Station, Iowa State College, Ames, Iowa, 1948 to date.

Author or co-author of over 40 publications in the field of poultry products technology; Chapter 15, 1946 Applications Volume, ASRE Data Books; co-editor of "Advances in Food Research"; articles in trade and technical magazines.

Member, Amer. Assn. for Adv. of Science; Poultry Science Assn.; Former member, editorial board, *Poultry Science;* member, Amer. Chemical Society; Inst. of Food Technologists (past chairman, Committee on Educ. and Curriculum).

Winner of the 1949 Christie Award presented by Poultry and Egg Natl. Board.

At present, Associate Director, Iowa Agric. Experiment Station, Iowa State College, Ames, Iowa.

Fig. 2. The Effect of Carbon Dioxide on the Keeping Quality of Eggs.

appearance of the opened egg. (Obviously, in addition to the changes shown, if the egg were fertile and at temperatures above 80–85 F the embryo would have grown and the appearance of the egg would have been objectionable. Infertile eggs are produced in quantity in certain areas of the country, but unfortunately this is not generally true for eggs produced in the Middle West.) The marked flattening of the yolk and thick white which occur at the higher temperature make the egg unsuitable for serving poached or fried. There is a loss of flavor accompanying these changes though it is less marked than the physical changes just mentioned. No great chemical alterations seem to accompany these changes, although there are progressive increases in loosely-bound nitrogen, inorganic phosphorus, fluorescence of the white, and water content of the yolk; there is a loss of carbon dioxide from the egg as a whole.

Quite obviously eggs badly contaminated with **bacteria** and **molds** usually undergo marked **decomposition.** Some of the more common end results of microbiological action are black, red and green rots. It is worth mentioning, however, that occasionally eggs can be heavily infected with microorganisms without there being any objectionable appearance, odor, or flavor. Fresh, clean eggs seldom contain any bacteria; if these eggs spoil during storage because of bacterial or mold growth, it is because they have become wet or have been held at excessive humidities.

Egg flavor is affected by many factors, including the feed and individuality of the hen, presence of bacteria and molds, natural chemical breakdown and, most important of all, by absorption of odors from the surroundings. Lemon-flavored egg is a good example of a defect of the latter type.

Control of Quality

1. **Appearance.** **Changes in temperature** and **carbon dioxide** play very important roles in preventing changes in the appearance of eggs during storage. There is every advantage in lowering the temperature to the lowest possible degree without freezing (29–30 F), if eggs are to be kept in good condition for very long. **Fig. 3** shows the effect of carbon dioxide content of the storage air on the appearance and flavor (due to chemical changes) of stored eggs. The rectangular area shows the range of optimum concentration under commercial cold storage conditions. This same effect can be obtained also by sealing into the eggs the proper amount of carbon dioxide by oil dipping within 12 to 24 hr after laying. Recently stabilizing the thick white and killing the embryo has been accomplished by heat-treating the shell eggs. It has not been clearly demonstrated whether or not this "thermo-stabilizing" prevents yolk flattening and off-flavor development. None of these developments has been adopted to any great extent in the United States. Reliance is being placed almost entirely on temperatures within

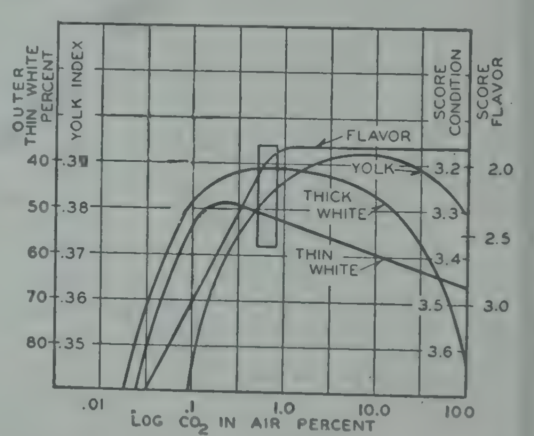


Fig. 3. Summary Data on Eggs Stored 37 Weeks at 30 F.

the range of 29 to 31 F for maintenance of quality during storage.

2. **Bacteriological spoilage.** The storage of dirty or improperly cleaned eggs is the most common source of bacteriological spoilage. A large percentage of the contents of dirty eggs is contaminated with bacteria. Improper washing increases the contamination but removes the evidence of dirt. Invariably most improperly cleaned eggs spoil during long storage. Insufficient research has been done to describe a perfect method for washing eggs for storage and it is probably not yet safe to recommend any procedure. Eggs known to be cleaned should probably not be stored at all but should be marketed promptly or else frozen or dried. "Sweating" of eggs removed from storage rooms gives rise to a serious contamination of the egg contents. If such eggs are held for an extended period thereafter considerable spoilage results.

3. **Mold spoilage.** Mold growth on eggs can be controlled easily for long periods of time by keeping them in air below 85 percent rh. However, such eggs will lose an appreciable amount of water under these conditions (commonly termed shrinkage due to increased air-cell size), and commercially this lowers their market value. On the other hand, most molds grow luxuriantly on eggs if the relative humidity at the shell surface is more than 96 percent. A slight growth commonly called "whiskers" occurs at 90 to 94 percent. The latter is often used as an indication of the desirable humidity level, although if eggs are kept at these humidities for extended periods the mold will penetrate the egg.

The optimum humidity for egg storage as ordinarily determined in the aisle of the storage room depends on a number of factors: Air circulation, dunnage, moisture content of cases, fillers and flats, fluctuation of temperature, etc. Empirically it has been found safe to use 85 to 86 percent when no artificial circulation of air is used, and 87 to 92 percent when positive circulation is used.

Fillers, flats and cases are sometimes treated with **chemicals** to minimize mold growth. The chlorinated-orthophenyl phenates (sodium salt) have been recom mended for this purpose. They have not yet come into general use.

Eggs for storage are sometimes dipped in a colorless, odorless **mineral oil.** This

Table 1. Summary of United States Standards for Quality of Individual Shell Eggs*

	Specifications of each quality factor			
Quality	U. S. Grade AA	U. S. Grade A	U. S. Grade B	U. S. Grade C
Shell	Clean, unbroken and practically normal.	Clean, unbroken and practically normal.	Clean, unbroken, may be slightly abnormal.	Clean, unbroken, but may be abnormal.
Air cell	Must not exceed $\frac{1}{8}$ in. in depth and may be practically regular or slightly wavy.	Must not exceed $\frac{3}{8}$ in. in depth and practically regular.	Must not exceed $\frac{3}{8}$ in. in depth; may show movement not over $\frac{3}{8}$ in., if air cell not over $\frac{3}{8}$ in. in depth it may be free.	May be over $\frac{3}{8}$ in. in depth and may be bubbly or free.
Yolk	Outline well centered and only slightly defined, free from defects.	Fairly well centered; outline fairly well defined and practically free from defects.	May be off center; outline well defined; may be slightly enlarged and flattened; may show definite but not serious defects.	May be off center, enlarged and flattened; may show germ development but no blood; may show other serious defects; outline plainly visible.
White	Clear and firm	Clear and reasonably firm.	Clear but may be slightly weak.	Clear; may be weak and watery; small blood clots may be present.

* Information taken from U.S.D.A., United States Standards for Quality of Individual Shell Eggs.

treatment greatly reduces shrinkage, and for such eggs the use of humidities above 85 percent is not of much practical value. If this treatment is to be effective in maintaining eating quality, the eggs should be treated within 24 hr after laying.

4. **Odor absorption.** The so-called **storage flavor** in eggs can be greatly minimized by choosing cases, fillers and flats which are new and which are relatively free of odor when moist. Further work needs to be done, however, if these odors are to be entirely eliminated from eggs stored for long periods of time. Quite obviously **rooms** for **egg storage** should be carefully **cleaned** and **deodorized** prior to their use for this purpose. Freshly prepared whitewash is commonly applied to the walls, ceiling and floor at the start of each egg season. In addition eggs should not be stored in rooms with other products, especially citrus fruits and onions.

5. **Nutritive value.** As far as we know at present the nutritive values of eggs are entirely retained during cold storage. However, studies of all of the nutrient losses in eggs during storage have not yet been made.

FROZEN EGGS

Yolk, white and whole (mixed yolk and white) eggs are usually commercially frozen in 10, 20 and 30-lb units and stored for long periods of time (6 to 12 months or more) prior to use by bakeries, confectioners, etc. Since **frozen eggs** are used almost exclusively in manufactured products, their quality is usually measured in terms of **performance** and **sanitary quality.** The sanitary quality problem is largely one of keeping down bacteria numbers, so that promptness of cooling, freezing and thawing is an important consideration.

During freezing and storage the egg yolk undergoes a gelation so that on thawing, yolk and whole egg are much thicker than before. In whole egg this change is not very objectionable to users but thawed yolk is quite pasty and difficult to use. Sugar and salt in varying proportions (up to 10 to 15 percent) are commonly used to obviate this difficulty.

It is believed by many in the industry that frozen eggs improve in culinary properties during frozen storage. The author is unaware of any carefully controlled experiments to prove this point. Furthermore, no extended storage studies have been made on frozen eggs in general, so we do not know the exact requirements for freezing and storing these products. Rather uniformly successful storage has been noted, though, when the products have been stored at +5 to −20 F for over a year.

DRIED EGGS

Enormous quantities (as high as 300,000,000 lb annually) of dried whole eggs have been manufactured during the past few years. Prior to 1939, relatively little egg was dried and most of this was fermented albumen and spray-dried yolk.

Albumen. Most albumen is fermented prior to drying. The removal of the sugar from the albumen which accompanies this treatment imparts complete stability to this product during storage. Fermented albumen with a moisture content below 15 percent keeps indefinitely without refrigeration. However, unfermented albumen keeps poorly at room temperature, especially if the moisture is above 3 percent; consequently this product should be stored at temperatures **below 50 F** if it is to be kept for any length of time.

Dried yolk. This product is usually spray-dried. Off-flavors and insolubility develop rather rapidly at room temperatures although these changes may not be important in some of the uses to which it is put. For general keeping quality dried yolk should be kept below 40 F.

Whole egg. This product is produced as both a flake and a spray-dried powder. Storage at room temperature for a prolonged length of time results in off-flavors and losses in solubility, color and vitamins A and B_1. Moisture contents below two per cent and gas packing improve keeping quality, but it is still recommended that this product be refrigerated to below 40 F if it is to be stored for any great length of time.

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18. COLD STORAGE OF FURS AND FABRICS*

THE use of cold air to protect furs and fabrics from moths and other household insects originated in 1895 in Washington, D. C. Little was then understood of the moth larvae, though it was general knowledge that the clothes moth was inactive in winter. Experiments were later carried on at various temperatures by Albert M. Read, of the Security Storage Company, in which L. O. Howard and C. L. Marlatt of the Bureau of Entomology of the United State Department of Agriculture collaborated. In one of several bulletins published on this subject, it is stated that

"Protection against injury by fabric pests of all kinds is assured by proper cold storage. Cold storage is depended upon for absolute protection by dealers in carpets, furs, and other valuable articles, such as stuffed animal heads, blankets, automobile robes, curtains, and upholstered furniture.

"It has been discovered that it is not so much the cold that kills. It is the sudden change from a cold to a warmer temperature and back to a cold temperature that most quickly results fatally. Thus it was learned that if articles infested with clothes moths were refrigerated at 18 F for several days, then suddenly exposed for a short time to 50 F, and then returned to 18 F, and finally held permanently at about 40 F, all moth life in them would be killed.

* A revision and amplification of Chapter 28, *Refrig. Data Book*, Refrigeration Applications Volume, 1st ed.—1940, entitled "Fur Storage," by G. N. Powell.

CLARENCE A. ASPINWALL, Author Chapter 18. Born 8/6/74 in Titusville, Pa. Began as clerk in Security Storage Company, Washington, D.C., June, 1892, and has been President of the company since 1918. Director of Amer. Security and Trust Company; Amer. Inst. of Refrign; Chairman of Assn. of Washington Warehousemen; Major, U. S. Army Res. Corps; Trustee of Geo. Washington University; Garfield Memorial Hospital.

Author, "Household Goods Warehousing in the U. S.," 1925; Chapter 16, 1946 Applications Volume, ASRE Data Books; several articles in *Foreign Service Journal* and *Furniture Warehousemen*.

Member, Certified Cold Fur Storage Assn.; Chevy Chase Club; Rotary Club; Metropolitan Club; Alfalfa Club, S.R.; Soc. Mayflower Descendants.

At present, President, Security Storage Company, Washington, D.C.

"If storage concerns aim at the destruction of clothes moths in articles intrusted to them, as well as the protection from injury of these articles during the period of storage, it is recommended that articles be exposed to two or three changes of temperature."[1]

While furs, garments, floor coverings, or any fabric may be stored and protected satisfactorily in cold storage without any preliminary treatment, it is now the general practice to give them all a thorough cleaning before they are placed in the cold vaults. Removal of the dirt, grease, insect eggs, and other matter improves the appearance of the articles, and lengthens their useful life, for the oxidation of these particles rots the fabric or pelt and hastens the process of decay.

In addition to the protection from insect damage cold storage has another and perhaps equally important advantage in preserving the vitality and lustre of furs and the tensile strength of fabrics. "Articles cold stored will come out even better than they were entered. This is particularly true of furs. The cold atmosphere prevents the drying out of the natural oils in the skin, and they, therefore, retain their softness and flexibility, in addition to which it has been found that the brilliancy of color is somewhat revived by storage in a cold atmosphere."[2]

There are fur garments now in cold storage in New York that have been there continuously for periods of from 20 to 33 years. When examined by an expert furrier recently they were found to be in excellent condition, "the pelts soft and pliable." A fair sized lot of furs, Persian lamb, seal and beaver garments, were removed from storage in Washington after 26 years continuous storage and the owner found them "in just as good condition as they were 26 years ago." There is countless testimony to the same effect.

Other reasonably safe and dependable methods of protection from clothes moths are available, methods less costly than cold storage. These include fumigation with hydrocyanic acid gas, carbon disulfide, carbon tetrachloride, and ethylene oxide-

carbon dioxide, and use of paradichlorobenzene and naphthalene flakes, and various insecticidal sprays.

There is no agent for making furs and other animal fabrics immune from the larvae of the two common types of clothes moth. Of the control methods developed, storage under refrigeration is of principal interest here.

Fumigation with various chemicals is effective in varying degrees. Some of the more powerful fumigants are poisonous vapors or are inflammable, and must be handled by responsible operators. Other vapors, gases, or sprays are effective for home use when properly applied. Fumigation does not immunize against reinfestation; care must be taken to store articles after fumigation in tightly closed, properly constructed containers. It is frequently desirable to store with the articles a quantity of volatile fumigant, usually in a crystalline form, or to provide means of introducing fumigants to the storage space.

High temperatures have a deleterious effect on furs, whereas **lower temperatures** are believed to improve the condition of the furs by enlivening the natural oils forming an inherent part of their structure. Humidity plays an important part in fur storage, and humidity control can readily be made a part of a refrigeration system. The judicious use of not only proper temperatures but also proper **temperature changes** will provide complete moth life extermination with no danger of reinfestation during the storage period.

A **combination** of **refrigeration and fumigation** is frequently employed. It is economical to employ a fumigation process to destroy moth life initially, and to store under refrigeration, which prevents reinfestation.

Climatic Effects on Moths

Studies of moth life have disclosed susceptibilities to temperatures and to temperature changes. Temperatures of 0 to 5 F, 5 to 10 F, and 10 to 15 F were found to have killed all moth eggs by the end of the first, second, and fourth day, respectively. When temperatures were held at 20 to 30 F, all eggs were not killed until the 21st day. In temperatures from 0 to 5 F, all larvae were killed by the end of the second day and in temperatures from 5 to 10 F by the 21st day. In general, activity commences at above 45 F and increases steadily with temperature to a maximum at about 55 F.

By exposing moth life to a temperature of 20 F for three or four days, then raising the temperature to 50 F for a day or two, and again dropping to 20 F for two or three days, and finally returning to a constant temperature of 35 to 40 F, all forms will be destroyed. This procedure will also effectively destroy other pests such as carpet beetles. Two or three repetitions of this cycle during the early part of the storage season insure complete destruction of moths, eggs, and larvae.

Furs are usually loaded into the cooler during a relatively short period, after which no further heat load from this source is introduced. For practical purposes, the fur load may be neglected and the refrigeration equipment selected on the basis of heat from other sources.

Storage Room and Refrigerating Equipment

The **design** of a fur storage room offers no special problems not involved in the general specifications for cold storage coolers. However, as furs are valuable and usually insured, it is advisable to follow the insurance underwriters' requirements. **Insulation** ranges from 4 to 6 in. of corkboard or its equivalent. It is essential that insulation be thoroughly waterproofed to eliminate moisture diffusion.

Coolers are frequently given an **inside finishing coat** of plaster or mortar. It is essential that this finish should be thoroughly dried before a room is placed in service. Otherwise, difficulty may be encountered from high humidity and frost accumulation.

The **racks** from which furs are hung are usually pipe, in a doubledecked framework. Horizontal bars, from which coat hangers are suspended, are usually spaced on 24-in. and 36-in. centers, thus providing natural aisle spaces. A set of lower bars is usually 60 in. above the floor, with an upper deck

120 in. from the floor. Ceiling height of about 12 ft is usually sufficient, although it is often higher to provide space for more than two decks. As a guide in determining the amount of rack space and room size necessary, it is usual practice to allow one foot of rack for each five or six garments.

There is considerable difference of opinion regarding the merits of **covering furs** while in **storage.** Some operators prefer to cover all items with individual covers, whereas others believe it necessary to protect only white garments. In any event, such covering is only for protection against casual dust and dirt. Coverings are made of light cloth or paper.

It is recognized that human occupancy and lighting loads in actual practice may not exist during the killing period since little or no work generally is done in the storage at that time. However, these loads are included in the calculations, since the excess capacity thus provided will be applied to the removal of the sensible heat of the furs themselves and thus permit a more rapid pulldown from the holding to the killing temperature. This allowance is desirable in view of the method of selecting equipment for the killing condition on a high running time basis, as outlined below.

If an **auxiliary room** for **killing** is used, calculations are made in the same manner. This room should be insulated with at least 3 in. of corkboard or its equivalent when located within the main storage room or 6 in. if located outside the main room.

Use of Unit Coolers

Various types of **cooling coils** have been used for fur storage work, such as direct expansion pipe coils, circulating brine pipe coils, and direct expansion finned coils or unit coolers as in **Fig. 1.**

It is necessary to make selection according to established capacities and characteristics of coolers and condensing units. Selection may be reviewed with respect to several **classes** of service.

1. For holding conditions of 35 to 40 F —only unit coolers and condensing unit.
2. For holding conditions and killing conditions with two separate rooms—a complete and separate system for each room.
3. For holding and killing conditions in the same room—unit coolers and condensing unit.
4. For holding and killing conditions in the same room—unit coolers and two-speed condensing unit or unit coolers and two condensing units.

In general, the characteristics of most unit coolers are such that the desired **relative humidity** of **55 to 65 percent** will be maintained when the units are operating on a temperature difference of 20 to 25 F between average refrigerant temperature and average cooler temperature.

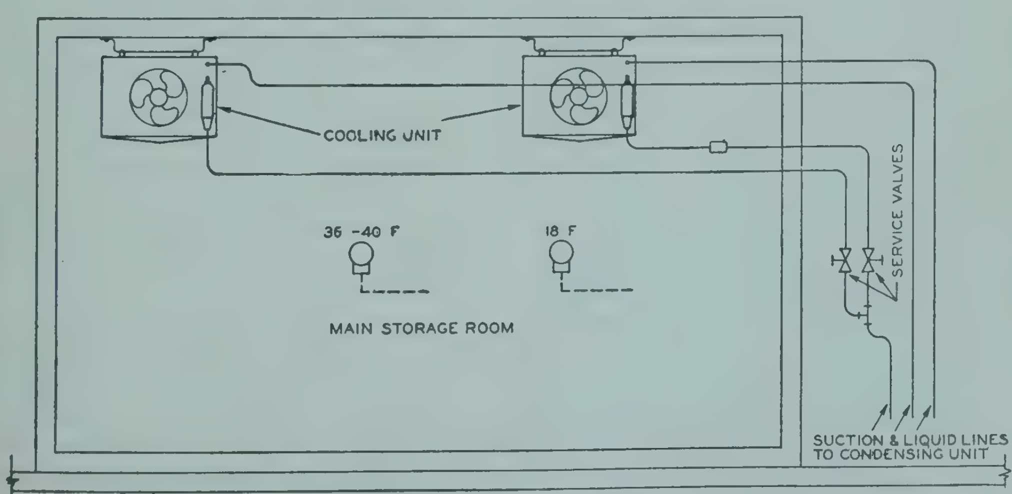

Fig. 1. Cooling Units Used to Obtain Killing Temperatures. Same Arrangement Used when Holding Temperatures Only Are Desired.

Under class 1, where holding at 35 to 40 F is alone to be accomplished, it is permissible to select equipment on the basis of 18-hr running time per day. On this basis, then, convert the calculated hourly load to the 18-hr rate by multiplying by the ratio 24/18. Thus, $13{,}188 \times 24/18 = 17{,}600$ Btu per hr. A unit cooler or coolers having this capacity would be selected. The average refrigerant temperature in the cooler or coolers could be from 11 to 16 F. The condensing unit would have this capacity at a refrigerant temperature of say 7 to 12 F, making allowance for suction line pressure drop. (The suction line pressure drop in actual practice must be carefully checked.)

For a class 2 installation, select equipment of the two systems in the same manner, to have the required capacities.

For class 3 (holding and killing), the selection is somewhat different. During the killing operation, it will be permissible to allow the equipment to run continuously or almost continuously if the killing conditions are to be maintained only periodically and for a matter of only three or four days at a time.

To select equipment for this plan, proceed as follows:

a. Determine the refrigeration loads for both holding and killing conditions. Select low side equipment having capacity equal to or slightly greater than the calculated killing load and with a temperature difference of 15 to 20 F.

b. Determine the refrigerant temperature at the cooling units and at the condensing unit, considering suction line pressure drop.

c. Select a condensing unit having capacity not less than the low side capacity determined under (a) at the refrigerant temperature determined under (b). Check the running time under killing conditions.

d. Determine the capacity of the same low side equipment with temperature differences of 20 to 25 F. Subtract these temperature differences from the desired average holding condition temperature. Determine the condensing unit capacity at the resulting refrigerant temperatures. From these, balance the condensing unit and cooling units, allowing for suction line pressure drop, maintaining a temperature difference of 20 to 25 F.

e. Check the running time under holding conditions. In most cases it will be found to be less than 18 hr per day.

In some cases it may be desirable to utilize a **two-speed motor** on the condensing unit when both holding and killing conditions are desired in the same storage. This is practical, provided the power source is either polyphase alternating current or direct current. However, such motors are considerably more expensive than standard single-speed motors. Moreover, the starting and controlling equipment is more complicated, expensive, and costly to install. In many cases, it is questionable if this additional expense will be compensated for by advantages from the use of a two-speed motor. Under certain conditions, it might be practical and economical to use two smaller condensing units to obtain the desired variation in capacity.

For cases of class 4, proceed as in steps (a) to (e) inclusive as just outlined above. Under (e) it may be found that the condensing unit capacity under holding conditions greatly exceeds the actual required capacity. Therefore, it would be practicable to reduce the condensing unit speed for this condition. Motors are usually available with reductions to ½ or to ⅔ full speed. In most cases the condensing unit operating at ⅔ speed, will have capacity

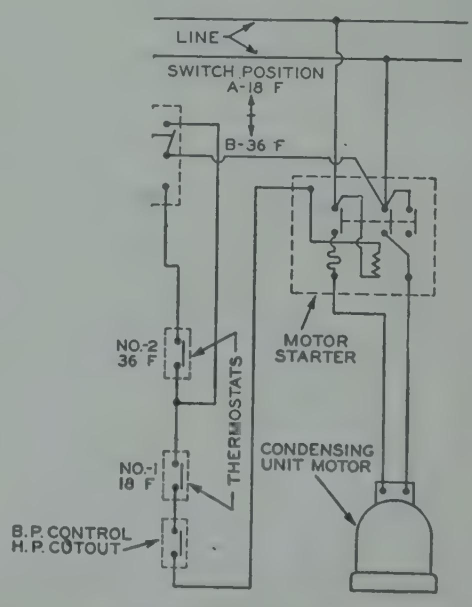

Fig. 2. Wiring Diagram.

nearly equal to that desired and will have an operating time of 18 to 20 hr per day.

Control and Defrosting

For classes 1 and 2, **control** is obtained by means of suitable room thermostats—one in each room—having proper ranges, or by suitable back pressure control. Back pressure control is satisfactory in many cases, since the temperatures to be maintained are not critical.

For class 3, two thermostats or two pressurestats and a double throw switch are required, **Fig. 2.** These are so connected that with the switch in one position, control is transferred to the low temperature instrument; in the reversed position control is transferred to the high temperature instrument.

For class 4, two thermostats or two pressurestats and a more elaborate motor starter are required. For changing manually from high speed to low speed a double-pole single-throw switch is required.

For the usual fur storage installation, means of artificially defrosting the cooling units are not considered necessary. However, the possible need for such equipment should be borne in mind. Such conditions should be considered as abnormal and not pertaining to the well constructed average installation. The need for defrosting may not be apparent until the equipment is placed in operation. Its subsequent addition to the installation should be considered an extra item for which the customer should expect to pay, inasmuch as its use is necessitated by conditions considered abnormal for most installations.

If artificial defrosting equipment is required it undoubtedly will be required during the killing condition. Several methods suggest themselves, such as the hot gas method or the electric heater method. Either method requires additional equipment. For example, the electric heater method as applied to class 3 or 4 requires a double-pole single-throw switch which cuts out the thermostats or pressurestats and energizes a multicontact relay. The latter is of such type that when energized it closes the electric circuit to the heaters and closes a solenoid valve or valves which must be placed in the liquid lines to the cooling units. Drain pans and drain lines constitute a problem to prevent their freezing when defrosting cooling units in temperatures below 32 F.

Fire Protection

The National Board of Fire Underwriters, after a disastrous fire in a fur cold storage house in New England, offered the following suggestions[3]:

Unprotected openings in the floors of buildings of fireproof construction may completely destroy the value of the floors in preventing spread of fire from floor to floor. Ducts for the circulation of air which serve two or more floors of a building may likewise destroy the value of the floors in preventing the spread of fire. The danger of fire spreading through the duct system may be greatly reduced by protecting the ducts with fire-resistant enclosures and fire dampers. Separate air cooling systems on each floor provide even better protection against such fire spread.

Fans which circulate air through duct systems serving two or more floors should be arranged to shut down automatically when the temperature of the recirculated air becomes excessive as from a fire.

Electrical equipment in combustible occupancies should be regularly checked and kept in first-class condition. Extension lights in garment storage rooms should be avoided.

An automatic sprinkler system, especially if equipped with alarm service to give immediate notice of system operation at some central alarm office, would be of decided value in reducing both fire and water damage in any warehouse containing combustible goods. An automatic inert gas extinguishing system would be an alternate method of protection, particularly applicable to garment storage rooms of moderate size.

A basement is a poor place for the storage of high-value goods readily subject to water damage.

In windowless buildings, it is of special importance that adequate aisle space be

provided to allow room for fire department operations inside the building. Fire departments should, for their own good, make regular inspections of such buildings to keep informed of conditions and to discuss the problem of fire department operations with the management.

The National Board of Fire Underwriters publish a pamphlet giving the standards of this board as recommended by the National Fire Protection Association for cold storage installations.[4] This pamphlet should be obtained and the recommendations therein followed by prospective builders of cold storage vaults.

Bibliography

1. Clothes Moths and Their Control, Bach, E. A. U. S. Dept. Agr., 1932.
2. *Fur Trade Review.*
3. Nat. Board of Fire Underwriters, Bulletin of Nov. 15, 1943. See also Building Code, and Recommended Fire Ordinance of the same.
4. Nat. Board of Fire Underwriters, Pamphlet No. 81, "Standards of the National Board of Fire Underwriters for Fur Storage." Oct. 1947.

If you searched this chapter for something which was not found in it, please let the editors know.

19. DISEASES AND DETERIORATION OF STORED PRODUCTS

FRUITS, vegetables, eggs, meats, poultry, and dairy products may be harvested, dressed, or packed some days before being presented for storage. Spoilage may have already set in. The warehouseman should acquaint himself with the condition of the shipment to guard against accepting products in which unusual amounts of deterioration have already developed. Storage in cooler or freezer will not improve the condition of the product. Even under optimum storage conditions spoilage may be expected to continue its development.

CYRIL O. BRATLEY (deceased), Author Chapter 19. Born 9/1/03, in Wichita, Kansas; died 5/9/48. Educated Univ. of Florida, BS, 1925; Cornell University, PhD, 1933. Formerly, Field Assistant, Fruit Disease Investigations, U. S. Dept. of Agric., 1926–28; Pathologist, in charge of Market Disease Laboratory, USDA, New York City, 1928–47; Asst. to Administrator, Research and Marketing Act, Washington, D.C., 1947–48; Senior Plant Pathologist, USDA, New York City.

Author of numerous technical bulletins on fruit diseases issued by USDA; Chapter 17, 1946 Applications Volume, ASRE Data Books; numerous articles dealing with plant pathology.

Member, Amer. Assn. for the Adv. of Science; Amer. Phytopathological Society; Amer. Soc. for Horticultural Science; Alpha Zeta; Sigma Xi; Consultant, War Shipping Administration; Member Scientific Advisory Council, Refrign. Res. Foundation.

JAMES S. WIANT, Author of Revisions, Chapter 19. Born 10/5/1900, in Kingston, Pa. Educated at Pennsylvania State College, BS, 1924; Cornell University, PhD, 1928. Formerly Plant Pathologist, Wyoming Agric. Experiment Station, 1928–31; present position 1931 to date.

Author, numerous Agric. Experiment Station and USDA bulletins and technical journal articles on diseases of conifers, potatoes, alfalfa and market, transit and storage diseases of fruits and vegetables.

Member, Amer. Phytopathological Society; Amer. Assn. for the Advancement of Science (Fellow); Alpha Zeta; Sigma Xi; Phi Kappa Phi.

At present, Senior Plant Pathologist, U. S. Dept. of Agriculture, New York City.

Periodic examinations should be made to ascertain the condition of each storage lot. When decay or some other injurious factor is found in undue amounts, the goods should be moved promptly.

The following outline, which emphasizes fruits and vegetables, has been prepared to assist the warehouseman in locating, identifying, and preventing the most **common types** of **spoilage** found in products he stores. Some of the diseases described do not develop in storage but are commonly found in lots offered for storage. The warehouseman should know about them as well as the diseases which may develop or originate in storage, in order to avoid disputes over responsibility for the damages. Detailed information on most of the diseases may be obtained by consulting the references listed at the end of the outline.

In the column giving **control measures,** temperatures higher than those recommended for the storage of the commodity are given occasionally. This should not be taken to indicate that the commodity should be stored at the higher temperature, but rather that the decay in question can be controlled at that point and below.

The numbers in superscript following the name of the commodity refer to more detailed publications listed at the end of the chapter, p. 237. The scientific name of the **causal organism** is given in parentheses following the common name in order to permit the nontechnical reader to identify references to the disease in the scientific literature. Technical terms have been avoided as much as possible; those used are explained at the first reference.

Diseases of Fruits

APPLES[10]

Disease	Control Measures
Alternaria Rot Dark brown to black, firm, fairly dry to dry storage decay centering at wounds, in calyx (blossom) cavity following washing injury, in core area, or in scald patches. One of the blackest of storage decays.	Prevent skin diseases and injuries that open way for infection.

Disease	Control Measures
Ammonia Gas Discoloration Circular spots centering at lenticels; dull green on unblushed side and brown to black on blushed side. Injury may disappear from slightly affected fruits.	Ventilate as soon as possible. Examine fruit for injury at various points in room because some sections may escape.
Apple-Cedar Rust (*Gymnosporangium*) Orchard disease only, infection occurring on young fruit. Greenish yellow, hard areas, usually on calyx end of apple, bearing pimples or tiny cup-shaped depressions. Flesh beneath spots is woody and usually greenish in color.	Remove cedar trees within one mile of orchard. Spray trees shortly after petals fall.
Bitter Pit Numerous small, brown, dry, spongy areas scattered in flesh, usually worse in blossom end. Those near surface are beneath small sunken bruise-like pits in skin. New areas may appear and develop in storage.	Provide orchard conditions for good set and steady growth of fruit. Store promptly at high humidity to prevent excessive moisture loss.
Bitter Rot (*Glomerella*) Scattered brown, definitely delimited spots on ripening fruit. Pink spore masses form concentric circles on the spot. Most common on summer apples from southeastern and central producing sections.	Control by orchard spraying and prompt storage of harvested fruit below 50 F.
Black Rot (*Physalospora*) Firm large lesions usually with concentric surface zones of brown and dark brown tissues, at punctures, calyx, or worm holes. Small black pimples are scattered irregularly on the larger lesions.	Spray orchard to control disease and puncturing insects. Refrigerate fruit promptly to 32F.
Blue Mold Rot (*Penicillium*) Soft, watery, tan to light brown areas that can be readily gouged out of the surrounding healthy flesh. White tufts of mycelium (fungus threads) turning bluish-green as spores are produced under moist conditions. Affected tissue has moldy or musty flavor and odor. Most important storage decay of apples.	Handle carefully to prevent skin breaks. Cool promptly to 32 F. Keep picking boxes, packing house and storage rooms sanitary. Whitewash walls or spray storage rooms annually with 0.8 percent solution of sodium hypochlorite or with other antiseptic.
Bullseye Rot (*Gloeosporium; Neofabraea; Corticium; Phialophora*) Fairly firm, brown decay with light tan centers. Develops late in storage season. Most prevalent on fruit from Northwest and Virginia.	Keep orchard healthy. Fall spraying with Bordeaux helpful. Cool fruit promptly. Move into trade channels as soon as disease appears.
Cork Strictly an orchard disease that does not develop in storage. Large patches of firm, dead, brown tissue deep in flesh of brightly colored fruit. Surface of apple may be bumpy. Areas larger than bitter pit.	Prevent drought conditions in orchard. Apply borax to soil around tree where boron deficiency exists.

Disease	Control Measures
Freezing Injury Watersoaked, rubbery condition of large areas or of entire apple. Vasculars (water-conducting strands) brown. Bruised areas in frozen apples large, with wrinkled gray to light brown surface. Moisture lost rapidly from affected areas. In refrigerator cars most prevalent on floor, at doorways and bunkers; in storage room most injury in bottom-layer boxes, near coils, or against walls next to freezer storage.	Heat car during sub-freezing weather. Prevent cold pockets in storage rooms by adequate air circulation. Handle fruit as little as possible while frozen. Thaw at 40 to 50 F. Move thawed fruit into trade channels promptly; do not allow it to become overripe.
Fruit Spot (*Mycosphaerella*) Orchard disease that does not develop in storage but becomes more apparent with change in color of fruit. Small (⅛ to ¼ in.) surface spots; dark red or black on red areas, dark green on yellow areas. Spot removed with thin paring which shows black flecks.	Control with orchard sprays.
Internal Breakdown Mealy collapse of internal tissue in over-ripe fruit. Surface often duller and darker than normal. Hastened by freezing, bruising, or presence of watercore.	Pick before overmature. Store or ship promptly at temperatures as near 32 F as possible. Watch stored fruit for signs of overripeness.
Jonathan Spot Slate-brown to black, very slightly sunken, skin-deep spots in color-bearing cells of skin, centering at lenticels.	Refrigerate promptly, because this disease is greatly aggravated by delayed storage.
Pink Mold Rot (*Cephalothecium*) Shallow, moist, mealy lesions usually centering at apple-scab spots. Generally conspicuous white to pink fungus develops at center of spot.	Do not hold picked apples in orchard but refrigerate promptly. Practically no development below 50 F.
Scab (*Venturia*) Old scab spots may continue to enlarge in storage. Disease also develops as small jet black spots in peel, often without breaking cuticle of fruit. All infections occur in orchard and resulting spots appear in storage despite maintenance of proper storage conditions.	Keep foliage scab-free by spraying. Use late sprays for fruit protection.
Scald Diffuse browning and killing of skin of fruit stored for several months. Ordinarily most prevalent in green portions.	Pick apples when well matured. Packing with ½ lb oiled paper per bushel will greatly delay appearance of scald.
Soft Scald Sharply defined oval or ribbon-like, slightly sunken areas in the skin. Affected tissue shallow and rubbery. Worst on Jonathan and Rome Beauty.	Allow no delay in storing. If apples are particularly susceptible store at 36 F.
Soggy Breakdown Light brown, moist, rubbery, definitely delimited areas in cortex of apple. Not visible	Same control as for soft scald.

Disease	Control Measures
on surface. Worst in Grimes Golden, Wealthy, and Golden Delicious.	
Water Core Hard, glassy, watersoaked regions in flesh of apple at core or under skin. Decreases in extent during storage but predisposes fruit to internal breakdown.	Keep trees well foliated. Pick as soon as mature. Watch fruit in storage and move before becoming overripe.

APRICOTS[11]

See **Peaches** because diseases are alike for these two fruits.

AVOCADOS[9]

Disease	Control Measures
Anthracnose (*Colletotrichum*) Scattered black spots covering firm decayed tissue that can be removed easily from surrounding flesh. Pink spore masses form on spots under moist conditions.	Prevent blemishes and other breaks in skin.
Flesh Darkening General dulling or graying of flesh color, particularly around base of seed. Also darkening of fibers throughout the flesh. Darkening is sometimes a varietal characteristic; at other times it is a result of storage at too low temperature.	Store hard or firm fruit at 42 F or above. Ripe fruit may be held safely as low as 32 F.

BANANAS[9]

Disease	Control Measures
Anthracnose (*Gloeosporium*) Shallow black spots on stems and elsewhere on ripening fruit. Under moist conditions pink spore masses cover center of spots.	Handle fruit carefully. Keep ripening rooms sanitary.
Chilling Injury Dull gray color in skin with increased tendency to darken upon slight bruising. Watersoaked areas may also appear in green fruit. Latex (sticky juice) in green peel meager and watery. Turning or ripe bananas more susceptible to injury than green fruit.	Avoid temperatures below 56 F unless fruit is to be exposed for very brief periods only.

CHERRIES[11]

Disease	Control Measures
Blue Mold Rot (*Penicillium*) Circular, flat spots covering conical soft, mushy decay that can be scooped out cleanly from surrounding healthy flesh. White fungus tufts turning to bluish-green develop on surface. Musty odor and flavor.	Prevent skin breaks. Market promptly. Refrigerate promptly to 32 F.
Brown Rot (*Sclerotinia*) See Brown Rot of PEACHES.	Control disease in orchard. Refrigerate promptly to 32 F. Treatment with carbon dioxide gas derived from "dry ice" in addition to regular refrigeration is helpful in controlling decay during transit.
Gray Mold Rot (*Botrytis*) Light brown, fairly firm, watery decay covered with extensive delicate dirty-white	Handle carefully. Refrigerate promptly to 32 F.

Disease	Control Measures
mycelium. On completely decayed cherries grayish-brown velvety spores may be found.	
Green Mold Rot (*Cladosporium* and *Alternaria*) Light brown, dry, firm decay lining skin breaks, that can be removed easily from surrounding healthy tissue. Mycelium on area fine and white above and dark green below.	Sort out cherries with cracks and other skin breaks at packing.
Pullularia Rot Thin extensive decay over surface of cherry causing it to become sticky.	Refrigerate promptly to 32 F. Handle carefully.
Rhizopus Rot Extensive soft, leaking decay with little change from normal color. Coarse mycelium and black sporangia (spore heads) are prominent under moist conditions. More prevalent in upper-layer packages in refrigerator car.	Refrigerate promptly to below 50 F.

CITRUS FRUITS[9,12]

(Including grapefruit, oranges, lemons, limes, etc.)

Disease	Control Measures
Alternaria Rot Usually at stylar end in oranges as a black, dry, deeply penetrating decay. In lemons as a slimy, leaden-brown storage decay of core starting at stem end.	Provide optimum growing conditions. Harvest oranges before overripe. Do not store tree-ripe lemons. Restrict storage period for other lots known to be weak.
Anthracnose (*Colletotrichum*) Small, scattered, leathery, dark brown, sunken spots. Internal affected tissues dark gray, fading through pink to normal color.	Keep trees healthy. Prevent skin breaks. Store for short periods only.
Blue (and Green) Mold Rot (*Penicillium*) Soft, watery, decolorized lesions which under moist conditions become quickly covered with blue or olive-green powdery spores.	Prevent skin breaks. Use antiseptic washes. Cool fruit to as near 32 F as practical.
Brown Rot (*Phytophthora*) Extensive firm, brown decay having a penetrating rancid odor. Chiefly on fruit from California and Arizona.	Submerge fruit at packing for 2 min in water at 115 F.
Freezing Injury Field freezing is found scattered through boxes. Transit and storage freezing is worst in exposed fruits in bottom-layer boxes or those nearest cooling coils. Affected fruits may show watersoaked areas in rind. Internal tissue disorganized, watersoaked, milky, and with rind flavor. Frozen fruit loses moisture, causing drying, separation of juice vesicles, and buckling of segment walls.	Keep temperature of fruit above 29 F, the freezing point.
Internal Decline In lemons, core tissues near stylar end break down and dry, becoming pink.	Maintain optimum moisture conditions in grove.

Disease	Control Measures
Peteca In lemons, collapse of small areas in albedo (white rind tissue), causing rounded pits lined with normal appearing skin.	Maintain good cultural conditions. Cull out affected fruits.
Skin Breakdown, "Aging" Small pits to large sunken, drying, discolored, firm areas in skin.	Pick before over-mature. Avoid overheating in packing house treatments. Wax fruit. Store for limited period only in fairly high relative humidity, 85 to 90 percent. Store limes at 42 F or above.
Stem-end Rot (*Diplodia; Phomopsis*) Pliable, fairly firm, extensive, brown decay starting at stem. Characteristic, sour, pungent odor. Found only occasionally in fruit from Arizona and California.	Keep grove thrifty. Dip harvested fruit promptly in 8 percent borax solution or other proven antiseptic. Use wraps treated with diphenyl. Cool promptly below 50 F.
Stylar-end Breakdown In Persian limes, large, gray to brown area of sunken, drying skin at stylar end.	Pick before fruit is too mature.
Watery Breakdown Soft, spongy, watersoaked condition of entire fruit after storage at low temperature. Resembles severe freezing injury but affected fruits are scattered throughout packages, have pronounced objectionable flavor, and are completely waterlogged.	Use recommended time and temperature for storage of each kind of citrus fruit.

CRANBERRIES[8]

Disease	Control Measures
Chilling Injury Affected berries tough, rubbery, with pink color diffused throughout interior.	Store berries at 36 F or above.
Fungus Rots (several fungi) Limited portions or entire berry brown, soft and collapsed. Some berries turned into "water bags."	Spray in field. Handle carefully. Reduce temperature to 36–40 F after harvest.

GRAPES[8]

Disease	Control Measures
Black Mold Rot (*Aspergillus*) Black, watery, leaky decay covered with dark purplish-brown powdery spore masses.	Cull carefully when packing. Refrigerate promptly to below 50 F.
Blue Mold Rot (*Penicillium*) Watery, mushy condition. Early production of typical bluish-green spores on berries and stems. Moldy odor and flavor.	Prevent deterioration in fruit by careful handling and prompt refrigeration, preferably to 32 F.
Gray Mold Rot (*Botrytis*) Early stage, "slip skin," with no mold growth. Later, "nest" of fairly firm decay covered with abundant fine gray mold and	Cull out decay when packing. Fumigate grapes with SO_2. Refrigerate promptly to as near 32 F as feasible. Use short storage

Disease	Control Measures
ayish-brown, velvety spore masses.	period for grapes harvested during rainy periods or following slight freezes.
hizopus Rot	
Soft, mushy, leaky decay causing staining lugs. Coarse extensive mycelium and black porangia develop under moist conditions.	Prevent skin breaks. Cool promptly to below 50 F.
ulfur Dioxide Injury	
Bleached sunken areas on berry at skin reaks or capstem attachment. Decolorized ortions have disagreeable astringent flavor. oes not appear in full severity until cool rapes are warmed.	Apply proper concentration of gas for recommended period; insure good distribution of gas.

MANGOES[9]

Disease	Control Measures
nthracnose (*Colletotrichum*)	
Large scattered black spots in the skin of pening fruits. Under moist conditions pink pore masses develop on spots.	Control disease on tree by regular spraying.

PEACHES[11]

Disease	Control Measures
rown Rot (*Sclerotinia*)	
Extensive firm, brown, unsunken, decayed reas turning dark brown to black in center nd early covered with dusty spore masses ellowish-gray in color. Skin clings tightly to enter of old lesions.	Control disease in the orchard. Prevent punctures caused by insects and otherwise. Refrigerate promptly to as near 32 F as feasible.
Cold Storage Injury	
Fruit loses flavor, becomes dry and mealy. Breakdown starting around pit is grayish brown, watersoaked or mealy.	Refrigerate promptly to 31–32 F. Breakdown appears earlier at 36–40 F. Store only for two to four weeks, depending on variety.
Pustular Spot (*Coryneum*)	
Common on peaches from West, occasionally on Eastern fruit. At first small purplish-red spots, later up to ½ in. diameter, brown, sunken, with white center.	Control with orchard sprays. Cool harvested fruit to below 45 F.
Rhizopus Rot ("Whiskers")	
Extensive fairly firm, watery decay with uniformly brown surface color. Skin slips readily from centers of lesions. Coarse mycelium; black spherical sporangia develop under moist conditions.	Cool promptly to below 50 F. Prevent skin breaks.

PEARS[10]

Disease	Control Measures
Alternaria Rot	
Surface dark brown to black. Decayed tissue gray to black, dry in center, gelatinous at edge, easily removable as core from surrounding flesh. Found late in storage season, usually at punctures.	Prevent skin breaks. Remove from storage on first appearance of trouble.

Disease	Control Measures
Blue Mold Rot (*Penicillium*) See Blue Mold Rot of Apples. Frequently appears in pears as small, flat, circular ("pin hole") spots scattered over surface of fruit.	Prevent skin breaks. Lower temperature promptly to 31 F.
Core Breakdown Often accompanies scald. Soft, brown breakdown in core area accompanied by acrid, disagreeable odor of acetaldehyde.	Do not allow pears to become overmature on tree. Cool promptly to as near 31 F as practicable. Ripen fruit between 65 and 75 F.
Freezing Injury Bartlett and Anjou pears exposed for four to six weeks just below their freezing point develop glassy, watersoaked external appearance with tan pithy area around core. Pears frozen sharply may break down completely or show abruptly sunken large pits where slightly bruised while frozen.	Keep transit and storage temperature from falling below 29 F.
Gray Mold Rot (*Botrytis*) Extensive, firm, dull brown, watersoaked decay with bleached border. Dirty white to gray extensive mycelium forming "nests" of decayed fruits.	Wrap fruit in copper-impregnated paper. Cool promptly to 31 F.
Scald Often accompanies core breakdown. Brown to black softening of large areas of skin and tissues immediately beneath. Affected areas slough off readily. Acetaldehyde odor and flavor prominent.	Pick before over-mature. Cool promptly. Store only for proper period. Cannot be controlled by oiled paper wraps.
Anjou pears often affected with a surface browning more superficial than above and distinct from it, resembling apple scald.	Anjou scald controlled by oiled paper wraps, same as apple scald.

PINEAPPLES[9]

Disease	Control Measures
Black Rot (*Ceratostomella*) Affected tissues extensive, soft, leaky, ranging from normal to jet black in color.	Treat freshly cut stem parts with 2.5 percent solution of benzoic acid in 30 percent alcohol. Prevent bruising. Cool to 50–55 F.
Brown Rot (*Penicillium; Fusarium*) Brown, firm decay starting at "eyes" or cracks. Common on overripe fruit.	Provide good growing conditions. Move before fruit is overripe.

PLUMS[11]

See **Cherries** because the diseases are the same for the two fruits.

STRAWBERRIES[8]

Disease	Control Measures
Gray Mold Rot (*Botrytis*) Brown, fairly firm, fairly dry decay. Dirty-gray mold and grayish-brown velvety spore masses present. "Nesting" common.	Handle carefully to prevent skin breaks. Cull out all diseased berries. Cool promptly to 40 F or below.

Disease	Control Measures
Leather Rot (*Phytophthora*) Slightly discolored large tough areas with indefinite purplish margins. Vascular system browned, flavor bitter.	Mulch plants to keep berries from contact with infested soil. Cool promptly to 40 F or below.
Rhizoctonia Rot Hard dark brown decay on one side of berry, usually small quantities of soil adhering. Develops but little after harvest.	Mulch plants to keep berries from contact with infested soil. Cull thoroughly.
Rhizopus Rot ("Whiskers") Mushy, leaky collapse of berries associated with coarse black mycelium and sporangia. Extensive red staining of containers from leaking juice.	Reduce temperature promptly to 50 F or below. Handle carefully to prevent skin breaks.

Diseases of Vegetables*

ARTICHOKE[5]

(Globe)

Disease	Control Measures
Gray Mold Rot (*Botrytis*) Most common decay of harvested artichoke. Reddish brown to dark brown firm rot. (See also footnote 2 below)	Practice sanitation in field. Refrigerate promptly. Store in dry place.

ASPARAGUS[4,12]

Disease	Control Measures
Bacterial Soft Rot Mushy, soft, watersoaked areas on tips and cut ends. (See also footnote 1 below)	Avoid excessive bruising of tips; precool to 40 F.
Fusarium Rot Watersoaked areas changing through yellow to brown, chiefly on tips. White to pink delicate mold.	Precool and ship at temperatures of 40 F or lower. Handle promptly. Keep tips dry on market.
Phytophthora Rot Large, watersoaked or brownish lesions at side of cut stalks. Lesions later extensively shriveled.	Precool to 40 F. Maintain low transit temperatures. Market promptly.

*Footnotes on Diseases of General Occurrence

	Control Measures
[1] **Bacterial Soft Rot** On various vegetables occurs as dark green, greasy or watersoaked, soft spots and areas in leaves and stems. Soft mushy yellowish spots or "soupy" areas on stems, roots and tubers of vegetables. Frequently accompanied by repulsive odor from secondary invaders.	Use sanitation practices during picking and packing to reduce contamination of harvested product. Where possible, reduce excessive atmospheric humidity, avoid bruising and injury. Shade harvested produce in field and reduce temperature promptly to 40 F or lower.
[2] **Gray Mold Rot** (*Botrytis*) Decayed tissues fairly firm to semi-watery. Watersoaked, grayish-tan to brownish in color. Gray mold and grayish-brown velvety spore masses conspicuous.	Use sanitation practices during harvesting and packing. Avoid wounds as much as possible. Lower the atmospheric humidity. Use storage and transit temperatures as low as otherwise practicable since decay progresses even at 32 F.
[3] **Rhizopus Soft Rot** Decayed tissues watersoaked, leaky, softer than those with gray mold rot or watery soft rot but not as soft as those with bacterial soft rot. Coarse mycelium and black sporangia develop under moist conditions. "Nesting" common.	Insofar as possible avoid injury and bruising. *Reduce temperatures promptly and maintain below 50 F.*
[4] **Watery Soft Rot** (*Sclerotinia*) Decayed tissues watersoaked, slightly pinkish or brownish-tan, very soft and watery in later stages, accompanied by development of fine white cottony mold and large oval black bodies called *sclerotia*. "Nesting" common.	Use sanitary practices in harvesting and packing. Cull out specimens with discolored or dead portions. Maintain as low temperatures as practicable inasmuch as rot progresses even at 32 F.

Disease	Control Measures
BEANS[4,12]	
Anthracnose (*Colletotrichum*) Circular or oval, sunken spots; reddish brown around border with tan centers that frequently bear pink spore mounds.	Use resistant varieties. Plant disease-free seed. Refrigerate harvested beans promptly to below 45 F.
Bacterial Blight (*Phytomonas*) Small, greasy-appearing, watersoaked spots in pod. Older spots show red at center with watersoaked area surrounding and penetrating to seed.	Keep field sanitary. Rotate crops. Use disease-free seed. Refrigerate picked beans promptly to below 45 F.
Bacterial Soft Rot (See footnote 1, page 225.)	
Cottony Leak (*Pythium*) Pods with large, watersoaked spots accompanied by abundant white cottony mold.	Sort out diseased pods in packing. Reduce transit temperature promptly to 50 F or below.
Freezing Injury Slight freezing results in watersoaked mottling in surface of exposed pods. Severely frozen beans become completely watersoaked and limp; they dry out rapidly.	Do not expose beans to temperature lower than 30 F.
Rhizopus Soft Rot ("Whiskers") Presence of coarse strands of fungus bearing glistening heads that turn jet black serves to separate this from other "nesting" decays. (See also footnote 3, page 225.)	
Russeting Chestnut-brown or rusty, diffuse surface discoloration on both sides of pods.	Permit no surface moisture on warm beans. Cool promptly.
Soil Rot (*Rhizoctonia*) Large, reddish-brown, sunken, decayed spots on pods. Cream-colored or brown mycelium and irregular, chocolate-colored sclerotia may develop. "Nesting" common.	Maintain transit temperatures of 50 F or below.
Watery Soft Rot Presence of large black sclerotia in white mold helps separate this from Cottony Leak. (See also footnote 4, page 225.)	
BEETS[5,12]	
Bacterial Soft Rot (See footnote 1, page 225.)	

Disease	Control Measures
CABBAGE[6,12]	
Alternaria Leaf Spot	
Small to large spots bearing brown to black mold. This spotting opens the way for other decays.	Avoid injuries. Maintain low humidity and temperature (30–34 F) in transit and storage. Practice sanitation in storage rooms.
Bacterial Soft Rot	
This slimy decay frequently starts in pith of cut stem or in leaf spots caused by other organisms. (See also footnote 1, page 225.)	
Freezing Injury	
Heads frozen slightly may thaw without apparent injury. Freezing injury is found first as brown streaks in stem, then as light brown watersoaking of heart leaves and stem.	Prevent any extended exposure to temperatures below 31 F.
Watery Soft Rot	
(See footnote 4, page 225.)	
CARROTS[4,12]	
Bacterial Soft Rot	
(See footnote 1, page 225.)	
Black Rot (*Alternaria*)	
Fairly firm black decay at crown, on side, or at tips of harvested roots.	Avoid bruising. Store at 32 to 35 F.
Freezing Injury	
Roots flabby and upon cutting show radial cracks in flesh of central part and tangential cracks in outer part.	Prevent exposure to temperatures below 30 F.
Gray Mold Rot	
(See footnote 2, page 225.)	
Rhizopus Soft Rot	
(See footnote 3, page 225.)	
Watery Soft Rot	
(See footnote 4, page 225.)	
CAULIFLOWER[6,12]	
Bacterial Soft Rot	
(See footnote 1, page 225.)	
Brown Rot (*Alternaria*)	
Brown or black spotting of curd.	Use seed treatment. Spray in field with Bordeaux mixture. Keep curds dry. Maintain low transit temperatures. Store at 31 to 32 F.
Freezing Injury	
Repeated or severe freezing results in watersoaking of stem and parts of curd. Pronounced spoiled cabbage odor develops. Affected tissues are rapidly invaded by soft rot bacteria.	Protect from repeated or severe freezing.

Disease	Control Measures
CELERY[4,12]	
Bacterial Soft Rot (See footnote 1, page 225.)	
Black-Heart Brown or black discoloration of tips or all of heart leaves. Affected celery should not be stored because of rapid development of bacterial soft rot.	Use care in irrigation. Use nitrogen fertilizer moderately. Harvest promptly after mature.
Early Blight (*Cercospora*) Circular pale yellow spots on leaflets. In advanced stages spots coalesce and become brown to ashen gray. No development of spots in storage, but affected lots lose moisture and fresh appearance.	Control in field by spraying or dusting.
Freezing Injury Characteristic loosening of epidermis can best be demonstrated by twisting leaf stem. Severe freezing causes celery to become limp and to dry out rapidly. Freezing predisposes celery to watery soft rot and bacterial soft rot.	Prevent exposure to temperatures below 30 F.
Late Blight (*Septoria*) Small ($\frac{1}{8}$ in. or less), yellowish, indefinite spots in leaflet and elongated spots on leaf stalk bearing black fruiting bodies of pinpoint size on surface and on surrounding green tissue. Development of blight in storage probably negligible but it opens way for storage decays.	Control in field by sanitary measures and fungicides. Store infected lots for short periods only.
Watery Soft Rot (Pink Rot) Often severe on field-frozen celery and on stock harvested after prolonged cool, moist weather. In early stages often has a pink color. (See also footnote 4, page 225.)	
CUCUMBERS[6,12]	
Anthracnose (*Colletotrichum*) Circular, sunken, watersoaked spots that soon produce pink spore masses in center. Later spots turn black.	Use disease-free seed and fungicidal applications in field.
Bacterial Soft Rot (See footnote 1, page 225.)	
Bacterial Spot (*Bacterium*) Small, circular, watersoaked spots; later chalky or moist with gummy exudate.	If possible, avoid shipping infected cucumbers. If not, then pack dry and maintain as low humidity and temperature as practicable
Black Rot (*Mycosphaerella*) Irregular, brownish, watersoaked spots of varying size; later nearly black. Black fruiting bodies sometimes present.	Exclude from pack if possible. Reduce carrying temperatures to about 45 F.

Disease	Control Measures
Cottony Leak (*Pythium*) Large, greenish, watersoaked lesions. Luxuriant, white, cottony mold over wet decay.	Exclude from pack if possible. Reduce carrying temperatures to about 45 F.
Freezing Injury Large areas in cucumber soft, flabby, watersoaked, and wrinkled, especially toward stem end.	Prevent exposure to temperatures below 31 F.
Low Temperature Breakdown Numerous sunken, slightly watersoaked areas in skin of cucumbers after removal from storage. Found on cucumbers stored for longer than a week at temperatures below 45 F.	Store at temperatures between 45 and 50 F for not longer than two weeks.
Watery Soft Rot (See footnote 4, page 225.)	

EGGPLANT[3,12]

Disease	Control Measures
Cottony Leak (*Pythium*) Decayed areas large, bleached, discolored (tan), wrinkled, moist, soft; later with abundant cottony mold.	Reduce carrying temperatures to about 45 F.
Fruit Rot (*Phomopsis*) Numerous, somewhat circular, brown spots later coalescing over much of fruit with pycnidia dotting older lesions. Very common decay of eggplant.	Control by sprays in field. Reduce carrying temperatures to about 45 F. Move fruit promptly if decay is evident at market.

LETTUCE[5,12]

Disease	Control Measures
Bacterial Soft Rot Commonest cause of spoilage in transit and storage. This decay normally the controlling factor in determining the storage life of lettuce. (See also footnote 1, page 225.)	
Tipburn Dead, brown areas along edges and tips of inner leaves. Little or no development of tipburn in transit and storage.	Keep affected stock well cooled and market promptly after unloading to avoid secondary bacterial rots.
Watery Soft Rots (See footnote 4, page 225.)	

MUSKMELONS[6]

(Including Cantaloupe, Honey Dew, etc.)

Disease	Control Measures
Alternaria Rot Irregular, circular, brownish spots sometimes with concentric rings; later covered with black mold.	Maintain transit temperatures of 40 to 45 F. Store cantaloupes at 32 to 34 F for periods up to two weeks only. If cold melons are to be held at room temperature they should be so stacked that condensed moisture will evaporate readily. Market promptly.

Disease	Control Measures
Cladosporium Rot Small black shallow spots later covered with velvety green mold. On cantaloupe extensive shallow area at stem-end or at points of contact of melons, that can be rubbed off easily.	Same control measures as for Alternaria Rot.
Fusarium Rot Brown areas on white melons; white or pink mold over indefinite spots on green melons. Affected tissue spongy, soft, with white or pink mold.	Avoid mechanical injuries. Reduce carrying temperatures to 45 F.
Low Temperature Breakdown Honey Dew and Honey Ball melons stored for two weeks or longer at temperature of 32 to 34 F sometimes show large, irregular, watersoaked, sticky areas in the rind.	Store these melons at 36 to 38 F.
Phytophthora Rot Brown, slightly sunken areas; later watersoaked and covered with wet, appressed, whitish mold.	Cull out affected fruits at packing. Reduce carrying temperatures to 45 F.
Rhizopus Soft Rot Affected melon soft but not soupy and leaky as in similar decay on other vegetables. Coarse fungus strands may be demonstrated in decayed tissue. (See also footnote 3, page 225.)	

ONIONS[4,12]

Disease	Control Measures
Ammonia Gas Discoloration Exposure of onions to 1 per cent ammonia in air for 24 hr causes surface of yellow onions to turn brown, red onions to deep metallic black, and white onions to greenish yellow.	Ventilate storage room as soon as possible after exposure.
Bacterial Soft Rot This decay often affects only one or two scales in the interior of the bulb. Decayed tissue more mushy than gray mold rot. (See also footnote 1, page 225.)	
Black Mold (*Aspergillus*) Black powdery spore masses on outermost scale or between outer scales.	Maintain as low humidity and as low temperature as otherwise practicable, preferably 50 F or lower.
Breakdown Gray, watersoaking of scales as in freezing injury, but only outer two or three affected. Entire scale may not be discolored, and no opaque areas found. Sometimes found in field.	Control not known. Store onions at 32 F rather than 40 or 50 F.

Disease	Control Measures
Freezing Injury	
Watersoaked, grayish yellow appearance of entire outer fleshy scales in slight freezing injury. All scales affected and flabby in severe injury. Opaque areas appear in affected scales.	Prevent exposure to 30 F and lower. Thaw frozen onions at 40 F.
Fusarium Bulb Rot	
Semi-watery to dry decay progressing up the scales from the base. Decay usually covered with dense, low-lying, white to pinkish mold.	Practice field sanitation. Do not store badly affected lots. Cull out infected bulbs in slightly affected lots. Refrigerate to 45 F or below.
Gray Mold Rot	
Usually starts at neck, affecting all scales equally. Decay often pinkish. (See also footnote 2, page 225.)	Cure onions well. Protect from rain. Store in dry cold storage (32 F, 70 to 75 percent rh).
Smudge	
Black blotches or aggregations of minute black or dark green dots on outer drying scales of white onions. Under moist conditions sunken yellow spots develop on fleshy scales.	Protect from rain after harvest. Store at 32 F and 70 to 75 percent rh.

PARSLEY[4]

Bacterial Soft Rot

(See footnote 1, page 225.)

Watery Soft Rot

(See footnote 4, page 225.)

PARSNIP[4,12]

Bacterial Soft Rot

(See footnote 1, page 225.)

Gray Mold Rot

(See footnote 2, page 225.)

Watery Soft Rot

(See footnote 4, page 225.)

PEAS[4,12]

Bacterial Soft Rot

(See footnote 1, page 225.)

Gray Mold Rot

(See footnote 2, page 225.)

Watery Soft Rot

(See footnote 4, page 225.)

PEPPERS[3,13]

Bacterial Soft Rot

(See footnote 1, page 225.)

Disease	Control Measures
Freezing Injury Outer wall soft, flabby, watersoaked, dark green in color. Core and seeds turn brown with severe freezing.	Prevent exposure to temperature below 30 F.
Gray Mold Rot (See footnote 2, page 225.)	
Rhizopus Soft Rot (See footnote 3, page 225.)	

POTATOES[7,12]

Disease	Control Measures
Bacterial Ring Rot Yellow, soft, cheesy decay of thin layer of tissue in vascular ring. Outer ½ in. of tuber and inner part may appear normal.	Use disease-free seed. Store tubers promptly at 36 to 40 F.
Bacterial Soft Rot (See footnote 1, page 225.)	
Fusarium Rot Brown to black, spongy, fairly dry; white or pink mold inside cavities in stored potatoes.	Avoid cutting and bruising during harvesting. Maintain well ventilated storage at 36 to 40 F.
Freezing Injury If frozen solidly the tubers become soft, rubbery, and exude moisture. Slightly frozen tubers show darkening of vascular ring and dull gray to black areas in flesh.	Prevent exposure to temperatures below 29 F.
Late Blight (*Phytophthora*) Reddish brown, granular discoloration of outer ½ to ¼ in. of tuber. Affected tissue fairly firm.	Keep dry. Store at 36 to 40 F. Market promptly.
Leak (*Pythium*) Large, metallic gray, moist, decayed area starting at end of tuber. Internal tissue granular, cream-colored at first, turning through reddish brown to inky black.	Prevent bruising. Refrigerate tubers to 36–40 F and keep dry.
Mahogany Browning Reddish-brown patches or blotches in flesh of tubers. Chippewa and Katahdin varieties most susceptible. Differs from flesh discoloration caused by freezing in being reddish-brown instead of gray.	Control by storing at 36 F or above, because lower storage temperatures cause the discoloration.
Net Necrosis Dark brown netting in outer flesh of tuber due to killing of vasculars. Most prominent at stem-end but extends well toward bud end. Increases during storage.	Plant only healthy seed. Reduce storage temperature promptly to 36–40 F because infected tubers show symptoms earlier at higher temperatures.

Disease	Control Measures
Scald and Surface Discoloration	
On early potatoes appears as sunken, injured areas, later turning black and sticky. Followed by bacterial rots.	Reduce exposure to sun and wind as much as possible after digging. Move promptly to market. Maintain as cool temperatures as possible.
Southern Bacterial Wilt	
Moist, sticky exudation from vascular ring when tuber is cut. Sometimes advanced mushy decay in center of tuber.	Avoid shipping infected tubers if possible. Market promptly.
Stem-End Browning	
Dark brown to black tissue, solid or in streaks, extending from ½ to 1 in. into the flesh from the stem-end. Develops during storage.	Reduce storage temperature promptly to 36–40 F. Higher temperatures allow rapid development in susceptible lots.

RUTABAGAS[6,12]

Disease	Control Measures
Gray Mold Rot	
(See footnote 2, page 225.)	
Freezing Injury	
Rare because this commodity can stand slight freezing without injury. Severe freezing causes watersoaking and light browning of flesh, and odor of mustard and fermentation.	Prevent repeated slight freezing or severe freezing.

SPINACH[5,12]

Disease	Control Measures
Bacterial Soft Rot	
(See footnote 1, page 225.)	
Downy Mildew (*Peronospora*)	
Field disease commonly found on market as pale yellow, irregular areas in leaves. Downy gray mold is present on the lower surface.	Control in field. Market the affected spinach promptly.
White Rust (*Albugo*)	
Slight yellowing of areas in leaf above white blister-like pustules filled with white masses of spores.	Control in field.

SQUASH[6,12]

Disease	Control Measures
Black Rot (*Mycosphaerella*)	
Dry, black decay covered by gray to black hard rind often bearing black pimple-like fruiting bodies. Usually centered at stem or wounds.	Plant disease-free seed. Prevent skin breaks on fruit; handle promptly; dip fruit in formaldehyde solution.
Dry Rots (*Alternaria; Cladosporium; Fusarium*)	
Small, deep, dry decayed areas. In black decay the tissue is easily lifted out of thimble shaped depression. Surface mold low-growing, either greenish black or pinkish white.	Prevent skin breaks. Avoid temperature below 50 F in storage.
Rhizopus Soft Rot	
(See footnote 3, page 225.)	

Disease	Control Measures
SWEET POTATOES[5,12]	
Black Rot (*Ceratostomella*) Greenish black decay frequently fairly shallow and sometimes circular in outline at surface.	Store at about 55 F.
Chilling Injury Brown tinged with black discolored areas scattered or associated with vasculars. Interior becomes pithy.	Store at 50 to 55 F. Often produced by exposure to lower temperature for only a few days, but sometimes symptoms not produced by exposure to as low as 32 F for a week.
Freezing Injury Soft leaky condition of flesh. Outer layer of potato dark brown.	Do not subject to temperature below 29 F.
Rhizopus Soft Rot (See footnote 3, page 225.)	
TOMATOES[3,12]	
Bacterial Soft Rot (See footnote 1, page 225.)	
Green Mold Rot (*Cladosporium*) Thin, brownish blemishes or black shiny spots of shallow decay later covered by green, velvety mold.	Use care in harvesting and packing. Do not hold for longer than 8 days below 50 F. Temperatures below 50 F retard coloring but hasten decay.
Late Blight Rot (*Phytophthora*) Greenish brown to brown, watersoaked lesions, later with fine whitish mold.	Apply field control measures. Cull carefully before packing.
Macrosporium Rot (California tomatoes with symptoms almost identical with those of Phoma Rot of eastern section.)	Control in field. Use care in harvesting and packing.
Phoma Rot Sunken, deeply penetrating, black lesions at edge of stem scar and elsewhere on fruit. Black pycnidia develop later. Decayed tissues firm, brown to black. Found in Eastern-grown stock.	Apply field control measures. Use care in harvesting and packing.
Rhizopus Rot (See footnote 3, page 225.)	
Soil Rot (*Rhizoctonia*) Small, circular, brown spots; later large, brown, fairly firm lesions with cream-colored or brown mycelium and irregular sclerotia.	Before packing sort out tomatoes with early lesions if disease is prevalent.
WATERMELONS[6]	
Anthracnose (*Colletotrichum*) Numerous greenish, elevated spots with yellow centers. Later sunken and covered with moist pink spore masses.	Apply field control measures.

Disease	Control Measures
Stem-end Rot (*Diplodia*) Brown, fairly firm decay usually starting at stem-end and affecting large part of the melon. Black pycnidia develop later.	At time of loading in cars recut the stems and treat cut ends with Bordeaux paste.

SPOILAGE OF BUTTER[2]

Disease	Control Measures
Moldiness Dark-colored mold development in and on butter.	Use cream with low mold count. Wrap butter in treated parchment. Prevent surface condensation. Store promptly at −10 F or below.
Rancid, Cheesy, or Putrid Flavor Objectionable or off flavor throughout package or scattered in regions. Due chiefly to bacteria. Sometimes flavor imparted from wooden tub.	Sterilize utensils and equipment. Have pure water supply. Use pasteurized cream. Dry wooden tubs to below 20 percent moisture content before using. Store promptly at −10 F or below. Store butter in room by itself.
Tallowiness Bleaching, poor consistency, and loss of flavor in butter particularly along edges of package.	Use tight package, wrap thoroughly in treated parchment.

SPOILAGE OF CHEESE

Disease	Control Measures
Dehydration Excessive loss in weight during storage.	Wax outer surface or wrap in moisture-resistant materials. Store at 65 to 75 percent rh.
Moldiness Development of extensive dark-colored mold on cheese and cheese containers.	Wax or wrap cheese. Prevent moisture condensation on surface. Keep rh. below 75 percent and temperature below 40 F, the exact conditions depending on variety of cheese.

SPOILAGE OF STORED EGGS[13,14]

Disease	Control Measures
Freezing Injury Shell usually cracked. Structure of white broken down and watery. Yolk gummy in consistency. When candled, yolk shadow quite dark. Contents of egg seem loose around air cell and often become frothy when twirled vigorously.	Prevent temperature from going below 28 F, the freezing point of eggs.
Large Air Cell (Moisture Loss) Air cell at large end of egg prominent. (Air cell in U. S. Special Grade, $\frac{1}{8}$ in. or less; in U. S. Extra, $\frac{2}{8}$ in. or less; U. S. Standard, $\frac{3}{8}$ in. or less; and U. S. Trade, over $\frac{3}{8}$ in.) Caused by loss of moisture through shell.	Maintain rh of 90 to 92 percent. Dip eggs in mineral oil.
Low White-Index White loses its thick and gelatinous consistency, becoming watery. A natural change caused by enzymes with lowering of pH.	Store promptly at 29 to 31 F. Dip in mineral oil.

Disease	Control Measures
Moldy Shells and Black Spots (Fungus)	
Gray to black fungus threads growing on shells of eggs that have been wet or are in high humidity. Odor and flavor musty. Surface discolored. Very thin, light-colored mold may disappear on handling and not cause injury.	Avoid fluctuations in temperature that permit condensation of moisture on shell. Hold rh at 90 to 92 percent. Use ozone 1.5 ppm in storage rooms. Mycostats (mold-arresting materials) may be used in crates, flats, and fillers.
Rots—White, Black, Mixed, and Addled Eggs (Bacteria)	
White rot, or "sour egg," is first stage in bacterial decomposition. When candled, egg appears watery and homogeneous, having no yolk shadow. When twirled, mixed dark and light streaks are visible. Contents yellow to dark in color, watery and mixed. Yolk may be partly solidified. Offensive odor present to greater or less extent.	Prevent moisture on surface after laying. Keep nests dry. Store promptly at 29 to 31 F. Do not store washed eggs. Pasteurize eggs by heat treatments.
Storage Flavors	
Off flavors absorbed from package materials and from other products in the storage room. Natural chemical changes in egg also finally detract from fresh flavor.	Use materials in fillers and flats that do not impart off flavors. Store eggs in rooms by themselves. Keep pH high by low temperature and oil dipping to retard chemical changes. Use ozone 1.5 ppm in storage rooms.

SPOILAGE OF STORED MEATS[1,15]

(Cooler Storage)

Bone Taint (Anaerobic bacteria)	
Gassy, putrid odor and flavor around bone.	Cool carcass rapidly.
Discolored Spots (Bacteria)	
Yellow, greenish blue to brown-black, or purple spots on surface of dressed meats.	Same control as for sliminess.
Loss of Bloom	
Disappearance of surface freshness by dehydration, moisture coating, or undue oxidation.	Prevent fluctuation of temperature that permits alternate drying and dampening of dressed beef. Keep rh about 90 percent but with some air movement.
Moldiness (Fungi)	
Gray to black, very fine fungus threads in spots and larger areas over surface. Odor and taste musty and moldy.	Use sanitation in all handling operations, particularly in chilling room, because the spores of the fungi are usually air-borne. Lower the room temperature as rapidly as possible to 32 F. Even at this temperature mold will continue to develop. Keep surface free of moisture. Trim moldy surfaces to a depth equal to height of mold growth.
Sliminess (Bacteria)	
Moist, slippery areas on flesh sometimes accompanied by small bubbles and a taint in odor and flavor. Usually found first in body cavity. Development more rapid in pork than beef or lamb.	Use sanitation in dressing and handling because bacteria get on meat chiefly during killing and handling. Chill promptly to 35 F or lower (38 F and above increase danger from bacteria). Keep temperature uniform to

Disease	Control Measures
	prevent condensed moisture. The use of ozone, carbon dioxide, and ultra violet light in storage rooms has been recommended.

(Freezer Storage)

Loss of Bloom	
Disappearance of surface freshness by darkening and drying.	Hold temperature low (−10 F or lower) and uniform. Keep humidity high. Use moisture-proof wrappings.
Rancidity	
Production of strong odor and flavor due to chemical changes in fats.	Hold at low temperature (−10 F or below). Use moisture vapor proof wrappings.

SPOILAGE OF STORED POULTRY[13,14]

(Cooler Storage)

Disagreeable Flavor (Bacteria)	
Off odor and flavor both before and after cooking, particularly in region of hip joints and kidneys.	Cool promptly to 32 F.
Green Struck (Bacteria)	
Green discoloration of the skin and flesh at 37 F and above.	Store promptly at 32 F.
Slimy or Slipped Skins (Bacteria)	
Slippery soft areas on skin.	Cool promptly to 32 F. Occurs only after long holding periods at relatively high temperature.

(Freezer Storage)

Freezer Burn or Pockmarking (Dehydration)	
Collapse of cells of flesh starting as light-colored spots around the feather follicles or where the flesh presses against wood of container. In severe cases after thawing spots show as sunken brown patches of skin.	Keep temperature low (−20 F) and uniform, humidity high. Use moisture-vapor-proof wrapping.

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If you searched this chapter for something which was not found in it, please let the editors know.

20. OZONE AND LIGHT

I. ULTRAVIOLET LIGHT

ULTRAVIOLET light is a powerful and, at the same time, feasible agent for destroying **bacterial infection** in the air or on food surfaces.[1,2] Other possible protective agencies are sulfur dioxide (Chap. 15) and carbon dioxide. Ozone will be considered later. Carbon dioxide is restricted by the fact that CO_2 retards growth of infections rather than destroying them; for discussion of CO_2 see pages 242 and 245.

The source of ultraviolet light is a low-pressure mercury-vapor arc lamp, the radiation from which is very largely at a wave length of 2537 Ängstrom Units, which is near the wave length of maximum germicidal power. The enclosing glass has a high transmission for 2537 radiation, and also transmits a few per cent of wave lengths below 2000, which produce ozone. The heat emitted by these lamps is so small that it has no appreciable effect on the surrounding temperature or the required refrigeration.

Such bactericidal lamps are made in several sizes, the most common one being approximately 30 in. in length. There is also a small lamp for small enclosures, particularly domestic refrigerators.

The radiant energy unit commonly employed is that corresponding to one click with the Rentschler Tantalum Cell,[3] the value of which varies between 220 and 360 microwatt seconds per sq cm of 2537 radiation falling on the sensitive surface of the meter. The exact value is furnished with each meter. Five 220 units will destroy approximately 50 percent of the more common bacteria whether floating in the air or resting on surfaces,[4] quite independently of the temperature or humidity.[5]

"Five of these units" is approximately the quantity of radiation received on a square inch of area in 5 min, if the distance from the center of this area to the center of a 30-in., 15-watt lamp (without reflector) is 18 ft, a line joining the centers being perpendicular to both.

If infections are subjected to a bactericidal agent for a generation time, the destruction will be increased at least five-fold, due to a sensitive stage which always appears in the life span of organisms during which they have less resistance to bactericidal agents such as ultraviolet light and ozone.[4] On the other hand, a bactericidal agent increases the generation time. Almost all of the important food infections, under ultraviolet light, and a temperature of 37 F or higher, have generation times of less than 24 hr, and an exposure of this length of time gives the five-fold killing. If the killing exceeds 50 percent, further growth is inhibited and infections are reduced.

A similar effective inhibition of the growth of **mold** is secured by a somewhat greater amount of 2537 radiation if the surfaces are relatively clean when the radiation is applied. Bacteria and mold several layers thick are sufficiently opaque to 2537 radiation to protect infection beneath from these inhibiting and destructive rays. Fresh cuts of meat, and sides and quarters from sanitary packing plants, large and small fresh fruits, freshly dressed fish,[6] clean vegetables, and cooked foods, which have come from satisfactory sources, rarely have sufficiently heavy bacterial or mold growth to interfere with the bactericidal effect of even low-intensity 2537 radiation.

ARTHUR W. EWELL, Author Chapter 20. Born 10/20/73 in Bradford, Mass. Educated at Yale University, AB, 1897; PhD, 1899; Univ. of Berlin; Johns Hopkins University. Formerly, Instructor in Physics, Yale, 1900–04; Inst. Prof. Physics, 1905–38; Director of Physics and General Science Departments, Worcester Polytechnic Institute, 1930–38; Capt-Major Air Service, U. S. Army, 1917–19, Head Bomb Unit AEF.

Author Physical Chemistry, 1909; Phys. Measurements, 1910, 1913; Chapter 18, 1946 Applications Volume, ASRE Data Books; many articles in trade and technical publications.

Fellow, Amer. Academy of Arts and Sciences; Amer. Soc. of Refrigerating Engineers; French Phys. Soc.; Newcomen Society. Awarded Hon. Dr. of Science, Worcester Polytechnic Institute, 1945; Vice President, Trustee, Governor Dummer Academy.

At present, Consultant, Westinghouse Elec. Corporation, Welsbach Corp., and several cold-storage plants.

Fig. 1. Ultraviolet Light Installation in Meat Storage.

Among the most extensive and important uses of ultraviolet lamps are meat storage at cooler temperatures (Fig. 1), large and small market coolers for meat, vegetables and other foods (Fig. 2), and display cabinets. They have made possible a high humidity with all its advantages and they also have permitted, as respects infection, somewhat higher temperatures. Thousands of installations testify to improvement in food and reduction of losses. One 30-in., or 15-watt bactericidal lamp for each 30 sq ft of floor space, or 250 cu ft, has proved a satisfactory installation practice.* For high overall efficiency the lamp or lamps must radiate continuously from a fixed position, preferably in the ceiling. Injury of foods by too great radiation intensity is likely with portable ultraviolet lamps in inexperienced hands.

The most striking use of ultraviolet lamps is in the high temperature, rapid tenderization of beef.[7,8] One day for small cuts and 44 hours for sides at 68 F under exact processing conditions will give approximately the same tenderization as several weeks at 35 F. The ultraviolet light does not contribute to the tenderization process, but makes it possible by eliminating the very rapid growth of bacterial infection accompanying such a high temperature and high humidity necessary during the processing to prevent discoloration and loss of weight. Several million pounds of beef are handled weekly by more than 25 packing plants using this process.

Bactericidal lamps are used to a limited extent, with success in this country and abroad, for controlling mold growth upon cheese in aging rooms (see section on ozone, page 242).

2537 Radiation is an effective **deodorizing agent** for many odors present in "clean" cold storage rooms, although with the modern bactericidal lamp the accompanying ozone is in this respect usually more powerful than the radiation. Neither radiation nor ozone will destroy certain putrefactive odors.

Certain foods should be kept a few feet from direct radiation from ultraviolet lamps. If too close, beef, pork, and lamb acquire some discoloration and a transitory

* With prospective improvements in the transmission of the glass, greater areas and volumes will be feasible.

burnt odor and taste which disappears upon cooking. Cheese and lettuce may be darkened. Butter, cream and lard may acquire surface rancidity. If the lamps are in the ceiling and the food on racks or on shelves, the distance from lamps to food is generally sufficient to protect against any such effect.

Radiation and ozone, by destroying bacterial infection, remove an important factor in impairment of surface color or "bloom" of foods, particularly meats. Obviously, only a small portion of any food will receive direct radiation. Some will receive a lower intensity of reflected radiation. Scattered radiation (i.e., radiation quite independent of the angle of incidence) will be much less intense than the reflected radiation but, on account of the short wave length, it will be several times greater than that with the same intensity of visible light. There is always a gentle air circulation which produces the equivalent of outside air changes by bringing infected air to the vicinity of the lamps where it is sterilized by the high intensity 2537 radiation near the lamps, returning to dilute the infected air at a distance.

As already stated, ultraviolet lamps for food storage should have glass which transmits a few per cent of radiation below 2000 Ängstrom Units and produces **ozone** for protection of surfaces reached by no radiation.[9] At cooler storage temperatures, a concentration of 0.1 part per million (ppm) of air, by volume, produces very appreciable bactericidal effect when the 2537 radiation is present for major bacterial protection. The maximum ozone concentration in food storage rooms accompanying the 2537 radiation very rarely reaches 0.3 ppm. A portion of the ozone absorbs 2537 radiation and is dissociated simultaneously with the absorption.

Prolonged exposure to ultraviolet radiation from these lamps is harmful to the eyes and even a few minutes' exposure at a short distance may cause some irritation. If a person is obliged to work in close proximity to an ultraviolet lamp, the eyes must be protected by glass and the face with a visor or mask. No injury is experienced during short visits to radiated rooms.

Another application of ultraviolet lamps is in **domestic refrigerators.** On account of the obstructions by the food, shelves, etc.,

Fig. 2. Ultraviolet Lamps in Walk-in Cooler.

extremely little direct, very little reflected, and restricted scattered 2537 radiation reaches the food. For this reason much of the protection is from the ozone. With concentrations of about 0.1 ppm, excellent protection is achieved, including destruction of taste and odor vapors, which become very objectionable when the humidity is high.[10] On account of the inevitable short distances between a lamp and nearby food, care must be taken in the design of lamp and fixture to prevent excessive direct radiation. The ozone concentration is so low that no rancidity from ozone is ever observed with sensitive foods during the relative short storage in a domestic refrigerator. (See also final section of the following discussion of ozone.)

II. OZONE

The molecules of oxygen, which constitute about 20 per cent of our atmosphere, have two atoms. The ozone molecule has three atoms. In the presence of bacteria, molds, odor- and taste-carrying vapors, and many other oxidizable substances, ozone loses the extra atom and is the most powerful oxidizing gas known—the bacteria being "burned up." Such oxidation is accelerated by increasing the relative humidity,[11] offsetting the greater deozonization (see below). Ozone has a great advantage over other oxidizers in leaving itself no other residue than common oxygen. Ozone is also decomposed by catalysts, including water vapor and many surfaces. The maximum natural ozone concentration in parts per million of air by volume in temperate zones is about 0.005 and the average is about 0.001.[12]

Ozone may be produced in many ways, only two of which are used in cold storage, namely, by an "ozonator" or by an ultraviolet lamp. In an ozonator, air is subjected to an electric discharge described as "brush," "corona" or "silent." There are two parallel or concentric electrodes, one or both covered by a dielectric to prevent a spark discharge. A blower forces air between the electrodes. When an alternating potential of 6000 to 30,000 volts (depending upon the thickness of air space and dielectric) is applied to the electrodes, a part of the oxygen of the air is transformed into charged oxygen atoms—ions—which conduct the electric current, and the air space acquires a violet hue. Some of these ions recombine to form three atom molecules or ozone.

There is also ultraviolet light of wave length 2537 Ångstrom Units in the air space. This radiation is absorbed by ozone with accompanying partial dissociation into ordinary oxygen. Apparently the electric field also produces some deozonization. It is therefore important to remove the ozone as quickly as possible after it is produced. For each design of ozonator there is a minimum air velocity for efficient operation. Sometimes a lesser air current is used to secure a higher concentration, but at the sacrifice of the total amount of ozone produced.

Increasing the frequency increases both the current and the yield of ozone, very high frequencies necessitating water cooling of electrodes. The relative humidity of the air passing through the ozonator must be low. Otherwise, the oxygen ions acting as "nuclei" cause water to be precipitated in the violet-colored discharge space. The yield of ozone will be sacrificed by the production of oxides of nitrogen of very low bactericidal value. Furthermore, the dielectric may be punctured by excessive current where the discharge distance is reduced by water drops. Oxides of nitrogen are never present in appreciable amounts with properly designed and operated ozonators equipped with dehydrators.[13]

Ozonators are rated in terms of grams of ozone per kilowatt hour. The concentration of ozone produced, and a statement of whether or not the power factor and transformer losses are included, should be given. The following figures illustrate the yields when these factors are included and dry air is used. Large American ozonators at 60 cycles and an ozone concentration of 2000 ppm or 0.2 percent give about 23 g per kw hr. The 1937 model Siemens & Halske ozonator at 10,000 cycles yields 50 g per kwhr at a concentration of one percent.

Determination of Ozone Concentration

The ozone concentration in a room can be approximately determined (within 10 percent) by hanging a special potassium

iodide starch paper at the point where the concentration is desired and determining the time, after wetting, for a match with one of three standard colors.

It can be calculated from ozonator and room data, by the following equations:[18]

$$m = kC,\ k = 0.7/t,\ C = 0.002 \text{ ppm}$$

where C is the equilibrium concentration in grams per cubic meter; m the amount of ozone introduced into the room per cubic meter per minute; and t, the time (minutes), after the ozone supply ceases, before the concentration drops to one half. The half time (t) depends upon the size and contents of the room. Fifty minutes is typical for a very large freshly whitewashed room, 30 min for a large egg room after a few months' storage, 10 min for a meat or cheese room and a few minutes for a well filled domestic refrigerator.[9,10]

In cold storage applications, where the order of concentration is generally of the order of 1 ppm and assuming the duration to be less than a generation time of bacteria, the bactericidal effect approximately follows the Reciprocity Law, i.e., it is proportional to the product of concentration and duration, or total quantity of ozone.[15] A concentration of a few tenths of 1 ppm kills 100 percent of the more common bacteria in a half hour exposure[11] whether suspended in the air or upon surfaces, in moderately high relative humidity.[11] The writer[15] and Smock and Watson[16] found the same to be true for molds. As with ultraviolet light, prolonged subjection to ozone over a generation time gives much greater killings than for a shorter period. Bacteria and mold several layers thick are nearly as impermeable to ozone as to ultraviolet radiation.

Use of Ozone in Cold Storage

The most important use of ozone is in **egg rooms.** To reduce shrinkage, i.e., to reduce the size of the void inevitable in every egg and the contamination accompanying the storage air which enters as the water vapor leaves, a high humidity is necessary. The growth of mold naturally increases rapidly with increase in water vapor in the storage rooms, but can be reduced by the use of ozone.

Each room is supplied with ozone by a brass or aluminum pipe from the centrally located ozonator, the amount supplied being regulated by a needle valve. The ozone is distributed throughout the room from a perforated block tin or aluminum pipe attached to the end of the brass supply pipe and located on the suction side of the fan or blower, or into the duct, which provides a general air circulation in the room. Ozone diffuses so rapidly that, without a duct system, if introduced at the suction side of a 15-in. fan near the ceiling of one end of a room of moderate size, e.g., 50×100 ft, there will soon be a uniform concentration. A minimum continuous concentration of 0.6 ppm of ozone in the air outside the cases is necessary and sufficient to prevent mold growth, if the eggs, cases and fillers are relatively clean. In a storage room filled with clean eggs and provided with suitable aisles and overhead ducts, a concentration of 1.5 ppm in the aisles will assure a concentration not below 0.6 ppm in the air adjacent to the cases. American observations, as well as English, have shown that a continuous ozone concentration of as high as 3.5 ppm for months will not injure eggs.[19,23]

Upon the basis of extensive experimentation in the laboratory and in commercial **apple storage** plants, Smock and Watson,[16] Watson[17] and Ewell[20] have published comprehensive reports. They have found that a concentration of 1 to 2 ppm, even for only a few hours a day, inhibits the growth of surface molds; reduces materially mold spore count, aerial growth of rotting fungus, and germination of spores; destroys offensive odors; and, to a less definite extent, retards ripening and mold.

These results were substantiated in part by later work reported by Schomer and McColloch,[27] who found that surface growth of fungi could be destroyed by use of ozone but that the treatment had little or no effect on established rot infections in apples. They found also that holding apples under ozone treatment at the rate of 3.25 ppm for 5 months impaired the flavor and caused a pitting injury in certain varieties. The fruit was not injured when the concentration of ozone was reduced to 1.95 ppm in daily treatments over a 5 months' storage period.

Small fresh fruit, such as strawberries, raspberries, currants, and grapes (particularly sweet wine grapes), are highly subject to mold. The writer has found that their storage period may be increased by 2 or 3 ppm of ozone applied continuously or for several hours each day, provided they are not so closely packed as to hinder access of ozone. **Sulfur dioxide** is very extensively and successfully used for protecting grapes during shipment and storage.[24] (See also Chap. 15.)

The **aroma** of aromatic fruits (strawberries, etc.) is so distinctly enhanced by ozone that some large distributors are using ozone for this purpose as well as for protection against mold. To some extent, ozone retards ripening by destroying the ethylene gas given off by many fruits, particularly when nearly ripe. In the oxidation of ethylene and other vapors given off by apples and citrus fruits, there is a noticeable but harmless "smoke" left in the room.

Ozone is unsurpassed for control of mold growth upon cheddar **cheese** during ripening. To prevent shrinkage a relative humidity of at least 80 percent is desirable. Even at 55 F, a few tenths of one part of ozone per million greatly reduces the frequency of necessary scraping and reparaffining. There are no injuries to any of the common varieties of cheeses if the concentration is 1 ppm or somewhat higher.

Ozone was, at least before this war, extensively used in **meat rooms** in Europe, a concentration of about 2 ppm being applied during the first 18 hr after dressing and about 1 ppm continuously in the holding rooms. In certain large meat rooms in this country, a concentration of 2 to 3 ppm for two 2-hr periods each day prevented the appearance of mold upon initially clean meat for eight weeks at 36 to 38 F and a relative humidity of 90 percent.[21] However, the new high transmission ultraviolet lamps, which provide both ozone and the bactericidal 2537 radiation, have largely displaced the use of ozonators in meat rooms (see previous section).

Ozone is useful for destroying (not simply masking) **odors** other than putrefactive in cold storage rooms and shipholds, especially upon a change of storage such as from citrus fruits to butter. For data upon the use of ozone in destroying odors, see reference 25.

Long exposure to ozone at a concentration of 1 ppm or higher may produce headache and irritation of the mucous membrane of the throat. It is therefore customary to turn off the ozone when men are working in the rooms continuously for many hours, for example, during receipt and removal of eggs. Storage goods, which are sensitive to rancidity, such as butter, lard, and fats, must be excluded from prolonged storage (more than one week) in rooms containing even low concentrations of ozone.

Ultraviolet Lamps as a Source of Ozone

Modern high transmission bactericidal lamps transmit a few per cent of the total radiation in ultraviolet light of wave length 1850, which changes some of the surrounding oxygen into ozone. The bactericidal effect of this ozone is roughly of the order of one per cent of that of the 2537 radiation, but under certain conditions it serves as a very valuable source of bactericidal protection.[26]

Bactericidal lamps (in an enclosure above 35 F where ozone is required) have the following advantages over ozonators:

1. Ozone is produced from the surrounding air, independently of the relative humidity, in contrast to ozonators which must be supplied with very dry air.
2. A constant ozone concentration is secured independently of the temperature (the greater deozonization with rise of temperature being offset by the increased ozone producing radiations.)
3. Lamps require less attention than suitable small ozonators, and the initial cost is lower.
4. Poorly designed or operated ozonators may produce oxides of nitrogen which are undesirable and which are never found when lamps are used.
5. Lamps have been used with marked success in cheese rooms since only a low ozone concentration is required. Strong 2537 radiation for a consider-

able duration causes surface darkening. Therefore, exposure to prolonged, intense, direct radiation must be avoided. Fortunately any discoloration is very largely eliminated by the customary multiple-tier storage racks, the frequent turning of the cheese, and the precaution of exposing no cheeses on the top shelf unless lamps with reflectors beneath are used.

6. In all cold storage applications of the ozone from bactericidal lamps, the concentration is too low for any injury to personnel even under long exposure, but suitable precautions should be taken to secure protection against the ultraviolet light radiation, if the rooms are occupied for considerable lengths of time.

Small bactericidal lamps have been used for several years in many thousand high-humidity (85 to 95 percent) domestic refrigerators made by manufacturers of relatively expensive cabinets. It is the experience of these manufacturers and that of the writer that the lamps are desirable for controlling growth of infection, and destroying odor and taste-bearing vapors accompanying a high humidity. Lamps make possible utilization of the great advantages of high humidity in prolonging the fresh quality and appearance of the food.[8] Destruction of taste and odor vapors in the refrigerator does not impair the natural aroma and taste of the foods.

Despite increase in the number of domestic refrigerator manufacturers installing small refrigerator sterilamps, the writer acknowledges that some other manufacturers report that they have not found these lamps of necessity or value in domestic refrigerators. As no details of these studies are available, it is impossible to explain the difference in results. The term "high humidity" is applied to quite a range and their humidities might have been appreciably lower than those of the writer and the above mentioned manufacturers.

The previous section on ultraviolet light describes the very important contribution of the ozone produced by high-transmission ultraviolet lamps in protecting surfaces in storage rooms not reached by the 2537 radiation.

Eggs and apples are carried in cases and boxes respectively which permit the entrance of gas, but which exclude radiation. Therefore protection must come from ozone. The storage rooms are large and the concentrations specified above are, at the present time, best obtained with ozonators.

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21. DISINFESTATION OF FRUITS AND VEGETABLES BY HEAT AND COLD

An unusual application of air conditioning is its use in the treatment of fresh fruit at **temperatures ordinarily considered injurious.** Such a process had its inception in Florida in 1929, when compliance with Federal plant quarantine regulations required devising a commercial method of treating citrus fruit which would insure heating to 110 F and holding it at that temperature for a period of 8 hr. The purpose of the treatment was to preclude development and dispersion of insect life that might be harbored in fruit destined for interstate shipment. In more recent years the same process has been used elsewhere in commercial treatment of oranges, grapefruit, avocados and papayas. In no case is the treatment given to known infested fruit; its purpose is to kill any insect life that may be present unobserved in apparently sound fruits.

A typical unit for heating commercial quantities of fruit consists of an **air conditioning apparatus** which introduces large volumes of heated, humidified air into a specially adapted room. Steam, preferably at low pressure, water, and air are so combined by the conditioner that the mixture can be continuously passed into and through the treating chamber at a constant temperature and humidity. A boiler to provide steam, a supply of cold water and electric current for operating a motor driven blower used to circulate the conditioned air through the room are also necessary. A sectional view of a typical installation is shown in **Fig. 1.**

A type of **room** found highly efficient includes insulated wall, ceiling, and door of conventional, reasonably air-tight construction with provision for introducing the conditioned air through a centrally located ceiling opening. It is withdrawn through a slatted false floor into a duct system formed by the joists, supporting the slatted floor, from whence it is returned to the air conditioning unit for subsequent recirculation. A floor drain equipped with a trap is installed so as to convey condensate from the room.

The essential point in the design of the treating chamber is to insure **uniform distribution of the circulating air.** In capacity the room is generally large enough to hold the maximum quantity of fruit to be treated at any one time. With citrus fruit, a convenient size measures approximately 20×20 ft with an 8-ft ceiling. Such a chamber will accommodate a carload or approximately 40,000 lb of this fruit, contained in 4-high stacks of open slat bottom boxes packed solidly throughout the room.

The air conditioning apparatus, which is most frequently located on top of the room, comprises a **closed circuit system,** consisting of a multivane blower with the suction inlet attached to a sheet-metal chamber containing steam jets, cold water sprayheads, water spray eliminators, steam radiator section, and drain pan for collecting and disposing of water spray and steam condensate unabsorbed by the air. This

A. Gordon Galloway, Author Chapter 21. Born 6/12/96 in Garrett Park, Maryland. Educated at Lehigh University, ME, 1920. Formerly, Principal Scientific Aid, Bureau of Plant Industry, U. S. Dept. of Agric., 1927–30; Chief Scientific Aid, Jan. to July, 1930; Associate Technologist, July to Sept. 1930; Bureau of Plant Quarantine, USDA, 9/30 to 1/32; Technologist, Bureau of Entomology and Plant Quarantine, USDA, 1/32 to 11/40; Senior Engineer, Technical Advisory Board, USDA, 11/40 to 4/41; Equipment and Engineering Services Division, Office of Plant and Operations, USDA, 4/44 to 2/49; Designated USDA Representative on the following Federal Specification Board Technical Committees—Vice-Chairman, Laboratory Equipment and Supplies, Thermometers, Chairman, Weighing and Measuring Devices, Materials Handling Equipment, Agricultural, Construction, and Road Building Machinery; Member of the subcommittees of the USDA Safety Council dealing with safety in the selection and operation of laboratory and scientific equipment.

Author of papers in technical and scientific journals; U. S. Government publications; Chapter 19, 1946 Applications Volume, ASRE Data Books.

Member of Amer. Assn. of Economic Entomologists; Amer. Helicopter Society.

At present, Senior Engineer (ME), Technical Services Division, Office of Plant and Operations, U. S. Dept. of Agriculture, Washington, D.C.

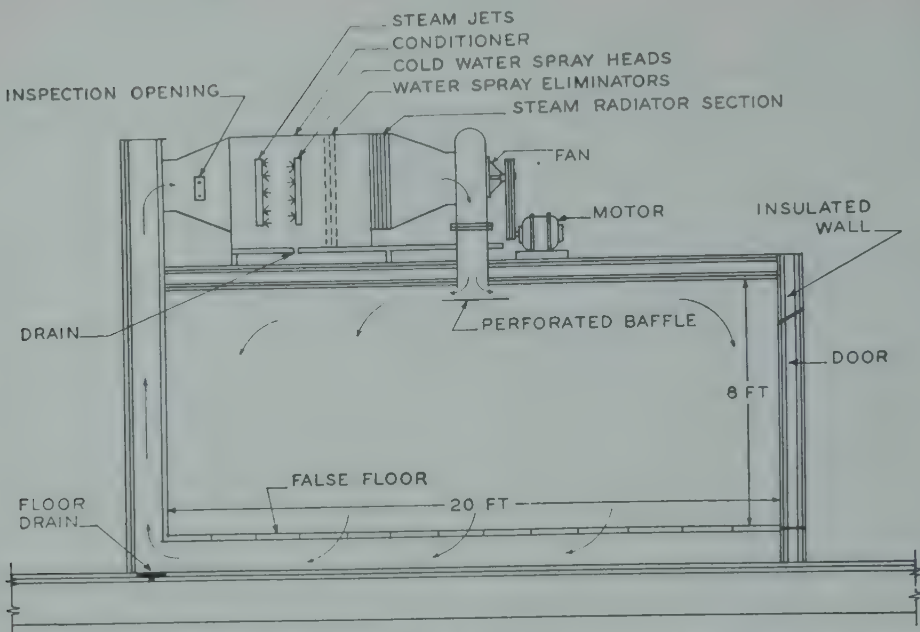

Fig. 1. Vertical Section of Treating Chamber, with Equipment; Arrows Show Direction of Circulation.

chamber is in turn connected to a duct through which air to be recirculated is withdrawn from the room through a wall opening into which the duct system beneath the slatted floor converges. The blower discharge is connected directly to an opening through the ceiling of the treating chamber.

Details of Commercial Practice

In order to heat 40,000 lb of fresh fruit to 110 F, it is obvious that a large amount of heat and a considerable amount of time will be involved to meet the treating requirements. In commercial practice, saturated air at a volume of 5,000 to 6,000 cfm, under sufficient static pressure to force it down evenly around all the fruit in the load, is introduced into the top of the chamber and withdrawn through the floor. The air is conditioned as to temperature and humidity before admission to the room, by properly mixing steam and water vapor in the air conditioner apparatus.

The use of cold water sprays in connection with the steam jets by which the air is heated, forms an important part of the process, since it is by this means that the mixture can be continuously maintained in a fully saturated condition at 110 F or any other desired temperature. The only control is a thermostatically operated regulator valve in the steam supply line. A function of continuously operating cold water sprays, in addition to automatically providing for full saturation of the air under all temperature conditions, is to insure any cooling of the air which might be necessary during the 8-hr holding period, to offset the heat of respiration of the fruit.

The success of the process is dependent upon the selection of sound fruit for treating, a well designed plant, and careful attention to and close regulation of the conditions in the treating chamber. With efficient equipment, properly operated, it is not unusual to heat a carload of citrus by this method from an initial temperature of 60 to 110 F in 8 hr or less and to maintain the latter temperature for the required 8-hr holding period with a variation of not more than two or three degrees between the coldest and warmest fruit in the room.

The process has been applied mainly to grapefruit and oranges. During the shipping season of 1943–44, a total exceeding 4,000 cars of such fruit received treatment before movement to market from one of the major citrus-producing areas of the United States. The process has also been successfully used to a lesser extent in commercial treatment of avocados and papa-

yas. When applied to the latter fruits it has sometimes been found desirable in the interest of avoiding fruit injury to hold the relative humidity of the treating air to 55 or 60 percent during the heating to 110 F. Conditioned in this manner, these fruits would then tolerate an 8-hr holding period at 100 F and 100 percent r h. Operation of the air conditioning apparatus under these circumstances involves use of the steam radiator section instead of steam jets for heating, during the period when saturated air is not required.

An optional treatment authorized for use in lieu of and for the same purpose as the 110 F 8-hr process consists of cooling the fruit to 35 F and holding it at this temperature for 15 days. In applying this **low temperature treatment,** the fruit, packed in commercial containers, is stacked in conventional cold storage chambers and cooled in accordance with the requirements. Usually it has been found necessary to augment the air circulation within the rooms by means of fans to obtain and maintain uniform temperature throughout the load of fruit. Even with adequate air movement and careful stacking of containers to enhance circulation, the process is slow and requires exactness and care in the operation of the refrigerating equipment. Dependent upon load size and arrangement, efficiency of the refrigerator room and skill of the operator, treatment by this process can involve a total period anywhere from 16 or 17 days to a month. Due mainly to this extent of the low temperature treatment, the process is not favored when time is an important factor in the commercial handling of fruit.

If you searched this chapter for something which was not found in it, please let the editors know.

22. REFRIGERATOR CARS

"THE people of the United States are as dependent upon refrigerator cars for their food supply as are the people of England upon her ships."[a] This apt statement made in 1916 still applies with equal force.

The average city dweller may never give this more than a passing thought but the truth of the quotation and the importance of refrigerator cars to American agriculture are never out of mind of the thousands of farmers who must use them to market their produce. By providing means for the dependable movement of shipments from producing areas to distant markets, refrigerator cars have had a major part in the transformation of American agriculture to a truly national industry.

Many now living can recall the time when each community was largely self-sustaining. Farms and farm communities have always been more or less self-contained. City markets formerly drew on the nearby countryside for meats, vegetables, and fruit. Summer was a season of abundance for fresh vegetables—and fruit, where it could be grown; fresh meat was obtainable mainly from local butchers and "fresh" eggs often were of dubious character. Winter was a season when the vegetable supply was limited to potatoes, cabbage, beets, carrots, and others that could be stored in cellars or in outdoor pits. During cold weather, however, fresh meat was available in abundance.

The advent of refrigerator cars and the perfection of shipping practices and of railroad operation have changed all this. The modern refrigerator car and fast freight service make possible a **continuous supply** of all kinds of **fresh perishable foods** throughout the year, not only in the large terminal markets but even in most small communities that can be served from the larger centers. This refrigerated car service is responsible for the growth and prosperity of many important agricultural producing areas in localities a thousand miles or more distant from their primary markets. Fast, dependable refrigerated transport has made possible the development of highly specialized agricultural industries in areas where climate and soil or other natural advantages are most favorable to particular crops, regardless of geographical location with reference to markets. As a result we now see, for example, more than 50,000 carloads of lettuce moving annually from California to Eastern markets. In 1947 more than 25,000 carloads of it came from a single shipping point, Salinas. Ten thousand carloads or more ordinarily come from Arizona.

Refrigerated transportation of fresh fruits and vegetables and other perishable products has given rise to huge growing, packing, and shipping enterprises and contributary industries that support many thriving communities and cities in remote parts of the United States. Brawley and Salinas, Calif., Yakima and Wenatchee, Wash., Weslaco and Crystal City, Texas, to name only a few of the most prosperous and progressive towns in America, have thus grown up in what would still be range country—or a great stretch of sagebrush

[a] Dr. M. E. Pennington. *The Waybill*, vol. 7, October 1916.

DURWARD F. FISHER (deceased), Associate Editor Section II and Author Chapter 22. Born 8/17/88 in Clarence, N.Y.; died 9/18/49. Educated at Michigan State College, BS, 1912; M. Hort., 1917. Formerly, Plant Pathologist, Fruit Disease Investigations, Bureau of Plant Industry, Soils, and Agric. Engrg., 1912–30; Principal Horticulturist in Charge, Investigations on the Handling, Transportation and Storage of Fruits, Vegetables, and Ornamentals and their Market Dieases, 1930 to 1949.

Author or co-author of numerous official bulletins and other publications of the USDA, pertaining to orchard fruit diseases, storage and transportation of fruits and vegetables, and market and storage diseases of fruits and vegetables. Associate Editor, Section II, and author, Chapter 20, 1946 Applications Volume, ASRE Data Books; numerous articles in the field of fruit diseases and the post harvest handling of horticulture products in trade and technical publications.

Fellow, Amer. Assn. for the Advancement of Science; Member, Amer. Soc. for Horticultural Science; Amer. Soc. of Refrig. Engrs. (Council 1940–42); Food and Container Institute; Botanical Society of Washington; Scientific Advisory Council, Refrign. Res. Foundation; Sigma Xi.

waste—if it were not for the railroad refrigerator car.

History of Refrigerator Cars

In early attempts to ship perishables by rail before the advent of refrigerator cars it was found that losses from deterioration in transit were too frequent and too large to leave a profit to the shipper. Ventilated cars of various kinds were tried with varying degrees of success. About 85 years ago the first shipments of fresh meat were tried in ordinary freight cars fitted with platforms at each end, upon each of which was placed about 3,000 lb of block ice. The ice was held in place by swinging doors suspended from the ceiling and could be replenished only when the car was empty.

The first patent taken out for a refrigerator car was that of J. B. Sutherland, November 26, 1867. Following this there was a rapid succession of patents on refrigerator cars, including the forerunner of the present brine tank car patented by D. W. Davis of Detroit, Mich. In this car strawberries were reported to have been successfully shipped from Cobden, Ill., to Buffalo, N. Y., and peaches from Dayton, Ohio, to New York City. A successful long distance shipment of dressed beef in this car made in September, 1869, is credited with being the beginning of the dressed beef industry. For a further discussion of the early development of the refrigerator car business see reference 10.

The importance of refrigerator cars and the extent to which they are now used can be seen from the fact that as of January 1, 1949 there were 130,618 refrigerator cars in operation in the United States and that the total movement of fresh fruits and vegetables via rail amounted to over a million carloads during 1947.[b] Shipments of meat, dairy products, and other products in refrigerator cars amounted to over a million more.

There are two general **types of refrigerator cars** in use today: (1) brine tank cars, used largely for meat and packing-house products, and (2) cars with basket bunkers used for most other products, including fresh and frozen fruits and vegetables.

It is sometimes said that the refrigerator car is the same today as it was 30 years ago. This is true only as it relates to the general design of the structure—a loading space, with brine tanks or ice bunkers at each end arranged to permit icing from the top of the cars.

The evolution of refrigerator cars from the date of their conception has been a very gradual process. It has employed the inventive genius of many men connected with the railroads and shipping industries. Many devices and arrangements of equipment to facilitate cooling in hot weather and to prevent freezing in cold weather have been conceived and tested. The U. S. Department of Agriculture has assisted in much of this work, being called on as a competent neutral agency to investigate or develop methods of shipping perishables during different seasons of the year from various parts of the country and to conduct disinterested tests on the merits of various kinds of equipment, the use of which was proposed from time to time. The Department continues these activities at the present time through the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the illustrations cited herein are taken largely from its records.

Prior to 1920 there was a great variation in the refrigerator car equipment of the various car lines and railroads. During the preceding decade much testing work was done to determine the relative effectiveness of cars with different thicknesses of insulation.[7,8] Refrigerator cars before 1920 were not generally equipped with floor racks; shippers had to build and install any **floor racks** that were used. Under these conditions there was no uniformity of design or construction; stringers were often placed crosswise of the car, partially or completely cutting off air circulation under the load; ice bunker **bulkheads** were often built so that the openings at the top and bottom were more or less obstructed by braces and other structural members. After much investigative work it was determined that the bulkhead openings at top and bottom should be at least 12 in. high, and that insulated solid bulkheads were superior to the non-insulated open or per-

[b] I.C.C. Statement No. 48100, as quoted in *Railway Age*, Vol. 126, No. 5, pp. 19–20, Jan. 29, 1949.

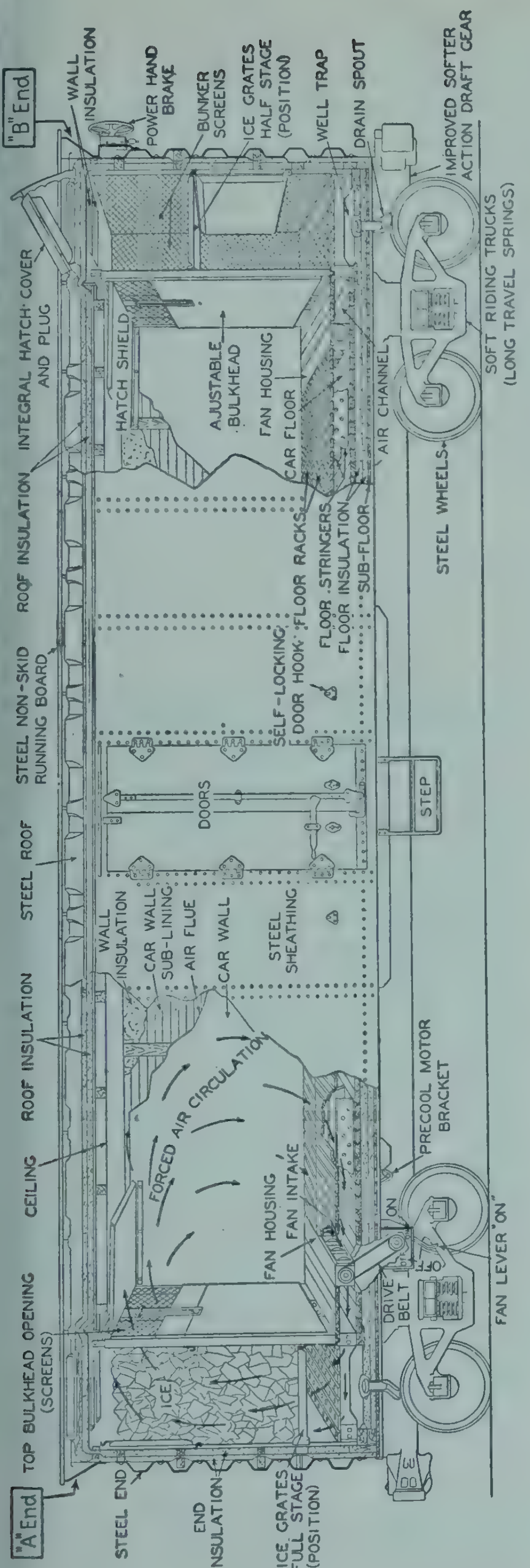

Fig. 1. Modern Refrigerator Car, Showing Improved Components.

forated bulkheads with which many cars were equipped.[3]

Government operation of railroads in World War I is almost never cited as an example to be emulated. However, there was one outstanding accomplishment of the U. S. Railroad Administration during World War I that merits attention here. It was the **"U. S. Standard Refrigerator Car,"** built to specifications drafted by a committee working under auspices of the Railroad Administration and composed of engineers representing refrigerator car lines, railroads, the Railroad Administration, and the U. S. Department of Agriculture.[c] In the car building programs during and following World War I these specifications were adhered to almost universally and the heterogeneous refrigerator-car equipment previously in use eventually was succeeded by more efficiently insulated cars equipped with water-proof floors, permanent floor racks, insulated bulkheads, and other features previously demonstrated to be desirable. Cars continued to be built to these specifications for the most part until an extensive new building program was undertaken about 1935. At this time the Mechanical Advisory Committee of the American Railway Association drafted specifications for a new refrigerator car building program. These cars were similar in general design to those previously built but differed in the main by having steel sheathing, thicker insulation, (3 in. in ends and sidewalls; $3\frac{1}{2}$ in. in floor and ceiling) and higher floor racks to allow more air space beneath; the bottom bunker opening differed in being confined to the space below the floor rack. Most of these cars were likewise equipped with adjustable ice grates to permit half-stage icing.[6] The total ice capacity of the bunkers in these cars ranged from about 10,000 to 11,500 lb of chunk ice as ordinarily used. If block ice were used somewhat more could be placed in the bunkers. The same general design continued to be used in later construction programs, but in some cases plywood sheathing replaced the steel.[d] Following the close of World War II another concerted car building program

[c] U. S. Railroad Administration, Mechanical Circular No. 7.
[d] *Railway Mechanical Eng.* 18, (6), 256–258. June 1944.

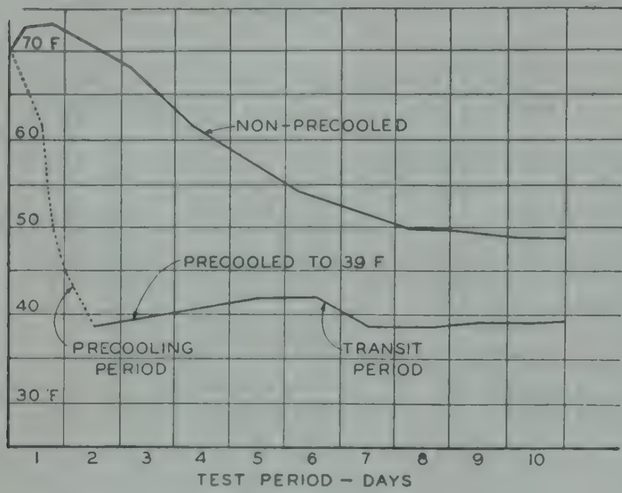

Fig. 2. Temperatures of Pears in Transit from California to New York City in Precooled and Non-Precooled 720-Box Loads, with Standard Refrigeration.

was undertaken by the major car lines Over 25,000 new cars have been built and put into service, and over 10,000 more are in course of construction, all being built to the same general specifications. These cars embody the first radical departure from the earlier pattern, particularly in providing forced circulation of the air from the ice bunkers. Other features include steel framing and sheathing, adjustable bulkheads, half-stage icing, 4 in. of insulation in ends and sidewalls and 4½ in. in floor and ceiling, improved floor racks, and sidewall air-circulating flues. All have the same inside dimensions and many have trucks with steel wheels for high speed traffic, and long-travel springs and soft-acting draft gears to provide an easier ride. **Figure 1** shows details of the improvements in the refrigerator cars now being built.

Performance of Refrigerator Cars

Shipments of perishables in refrigerator cars move under three types of **protective service,** depending in general on the commodity and the season of the year or outside weather conditions, and specifically on the order of the shipper. These services are: refrigeration, ventilation, and heater.

Refrigeration service. Under "standard refrigeration service" the car is initially iced to capacity, and reiced to capacity at all regular icing stations en route, and delivered to consignee with bunkers not less than three-fourths full. When additional cooling is desired, salt is used with the ice, the quantity being either a stated amount or a stated percentage of the ice supplied. If the load is **precooled** before shipment under this service, maximum protection is provided en route. It is used with shipments of the more highly perishable fruits such as peaches, pears, plums, berries, and other products. **Fig. 2** shows typical transit temperatures obtained in shipments of precooled and non-precooled Bartlett pears under standard refrigeration from California to New York. The fruit in car 8

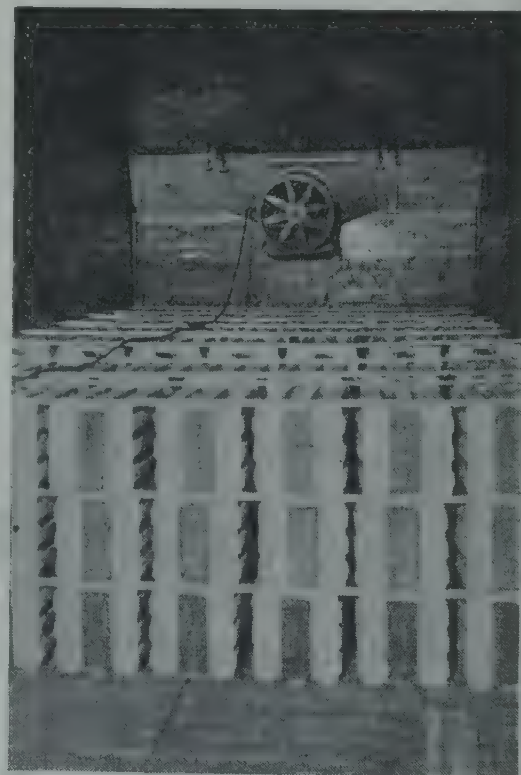

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Fig. 3. Portable Car-Precooling Fan Installed in a Refrigerator Car, Loaded with Cantaloupes. The Fan Assembly, Made in Four Parts, Consists of the Fan, the Central Tapered Fan Housing in which the Fan Unit is Installed, and Two Side Plates which Cover the Openings in the Bunker Bulkhead.

was precooled in the car after loading, using ice and salt in the bunkers and high speed propeller fans, especially designed for precooling, mounted in a panel covering the top bunker opening in both ends of the car; a similar fan is shown in **Fig. 3.** The fans are operated for 8 to 16 hr or longer as required to reduce the load to the desired temperature.

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Fig. 4. Precooling Carloads of Cantaloupes with Truck-Mounted Mechanical Refrigerating Units Driven by a Power Take-off from the Truck Engine.

Several other methods of precooling loaded cars are in use, including truck mounted mechanical refrigeration units **(Fig. 4),** permanently installed trackside unit coolers, and special arrangements for circulating air from large refrigerating plants operated by the railroads at train assembling points where may cars can be precooled at the same time **(Fig. 5).** For a more detailed discussion of precooling methods see reference 1.

Fig. 6 shows the effects on transit temperatures of shipping warm and precooled pears with and without salt used with the ice. In these tests some pears were precooled in a cold storage plant before shipment from the Pacific Northwest to New York. Fig. 6 shows the spread in temperature in different parts of the load and also shows that even with five percent of salt added to the ice, it is sometimes impossible to lower the fruit temperature in transit to the level of precooled shipments soon enough to retard ripening. The greatest trouble with non-precooled shipments is in the top layers, which are always the warmest in transit and may arrive so overripe as to require segregation from the rest of the load and prompt disposal—often at a discount in the case of pears, peaches, and other very perishable products.

If, on the other hand, the fruit temperature can be reduced to 40 F or lower before shipment and held below 45 F during shipment, the fruit can usually be kept in good condition during the ordinary transit period, provided, of course, it was in good condition when shipped. However, the temperature requirements vary with different commodities, oranges, for example,

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Fig. 5. Car Precooling at Plant of Santa Fe Refrigerator Dept., San Bernardino, California. Cold Air Is Blown into the Car at One End and Is Drawn Out at the Other.

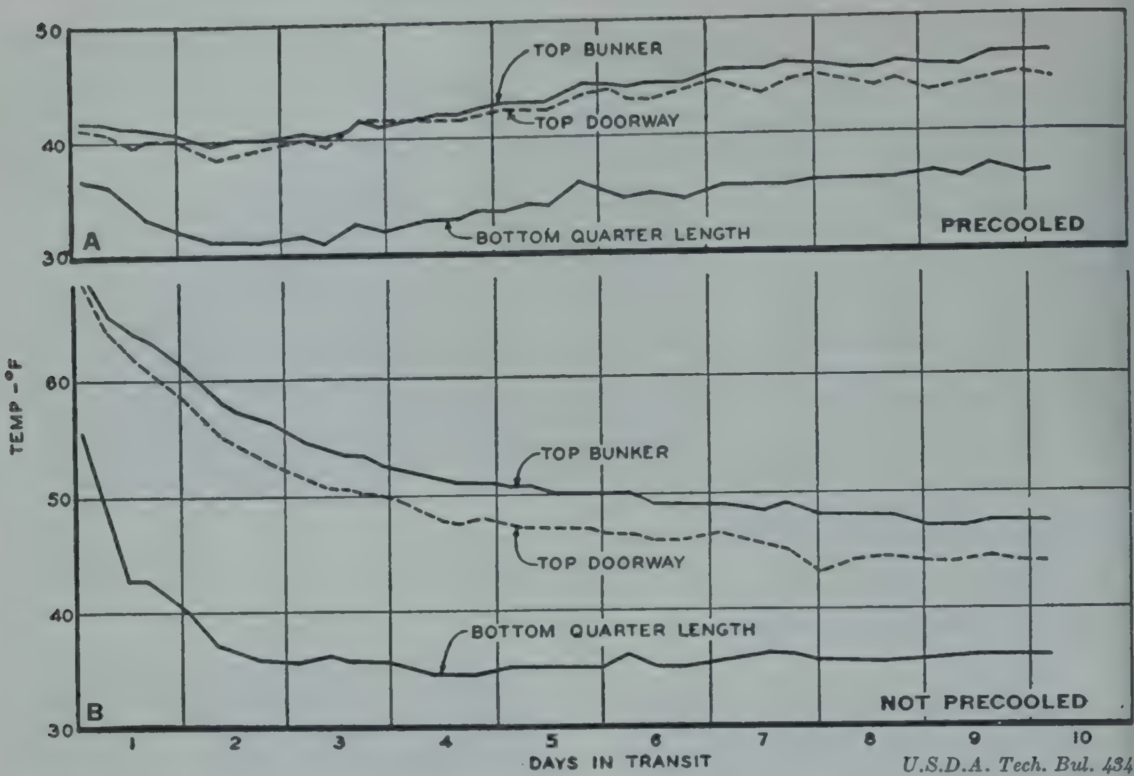

Fig. 6. Fruit Temperatures of Bartlett Pears in Transit from Medford, Oregon to New York City. A. 520-box load, precooled, standard refrigeration, 3% salt; B. 520-box load, non-precooled, standard refrigeration, 5% salt.

having been found less exacting than pears. Consequently, various forms of **modified refrigeration** have recently replaced standard refrigeration in the transportation of oranges from California to Eastern markets.[5] These modified refrigeration services are all cheaper than standard refrigeration and include variations in the number of times the cars are iced, the form of ice (block, chunk, or coarse ice), and the location of the ice in the bunkers. Upper half bunker icing (stage icing) has proved satisfactory for shipments of California oranges[6] as well as for lemons, tomatoes and other products. Where there is a shortage of ice, as frequently happened under wartime conditions, use of stage icing has been ordered by the Interstate Commerce Commission in shipments of citrus fruit and other commodities whenever cars suitably equipped are available.[e]

Body Icing

In "body icing" the ice is placed in the car in direct contact with the lading. This method is almost universally used in shipping lettuce, spinach, bunched carrots, and most other vegetables except string beans, lima beans, dry onions, potatoes, sweet potatoes, and other products which must be kept dry. Ordinarily crushed ice is placed in the package as well as over the top of the load **(Fig. 7)**, or with block ice interspersed through the load. At the present time **snow ice** is used more extensively than block ice or broken ice, "ice slingers" **(Fig. 8)** being used to blow 5 tons or more over the top of the load where it forms a complete blanket covering. The meltage from the ice tends to keep the produce fresh and unwilted. That **top icing** provides more rapid and effective cooling than does refrigeration from ice in the bunkers only is shown in **Fig. 9.** Sometimes bunker icing is used in addition to top icing where maximum protection is required. In the newer cars equipped with collapsible bunkers, the length of the loading space can be increased about 4 ft, when top icing only is

[e] ICC Service Order No. 210, May 1944.

Fig. 7. Snow Ice as Used in the Body Icing of Lettuce.
Photograph of a carload of lettuce from Salinas, California, at time of unloading in New York City, August, 1943. Note how ice fills spaces between crates as well as over top of load.

used, thus permitting heavier loads to be shipped. Due to recurrent shortages of ice in many areas and shortage of refrigerator cars under wartime conditions, loading of such cars to full capacity when bunkers are collapsed was required for all commodities that could be shipped under top ice.[f]

Railroads and car lines have found it most practical to have refrigerator cars generally adapted to **any type of service** that may be required, rather than to have special cars for special purposes. Therefore, while they have some of the latter, most of the cars are now equipped for general service. This was not always true, particularly in the shipment of body-iced vegetables. Before the advent of the U. S. Standard Refrigerator Car, use of body icing was attended with rapid deterioration in the efficiency of the cars because they were not designed for that purpose. The floors were not waterproofed, and icing of vegetables resulted in damage to the floor insulation, rendering the use of these older cars extremely hazardous for products not protected by top icing. In winter shipments excessive damage from freezing at the floor often occurred despite the use of car heaters.

In using top ice and package ice with shipments of vegetables, it is important not to use ice having **too low temperature.** Lettuce and endive freeze at about 31 F, and carrots, peas and most other vegetables that are top-iced freeze at about 30 F,[13] so that if they are placed in contact with ice having a temperature much lower than their freezing point there is danger that they will be damaged. When ice is used directly from the freezing tanks or from ice storages held at low temperatures, it may be too cold and should not be used until it has warmed up nearly to the melting point, 32 F.[4]

Ventilation service. In ventilation service refrigerator cars are used with hatches open and plugs out to take advantage of whatever cooling is possible by admitting **outside air.** Ventilation service is used extensively in the shipment of potatoes, sweet potatoes, tomatoes, citrus fruits, apples, and other commodities which are intended for immediate use, or which are shipped under weather conditions likely to provide desired temperatures without refrigeration or use of artificial heat. Different commodities are handled in ventilation service under different rules; for example, in providing standard ventilation service for apples the vents are closed when the outside temperature drops to 32 F or lower or is expected to drop to this level before the shipment reaches the next point where vents can be manipulated. Tomatoes and sweet potatoes, however, cannot endure long exposures to such low temperatures and the rules for handling these commodities provide for opening and closing vents at 45 instead of 32 F.

Ventilation service is cheaper than refrigeration service and is often used by shippers on that account even though it cannot be expected to furnish as good protection to the shipment. When the load is warm it can be cooled only if colder outside air **(Fig. 10)** can be circulated through the load effectively.

Ventilation service can be adapted to

[f] ICC Service Order No. 133, June 1943.

Fig. 8. Ice "Crusher-Slinger" as Used for Top Icing Refrigerator Cars Loaded with Celery in Florida.

quick cooling of warm loads by ordering vents left open above certain specified temperatures below 32 F, or to certain specified stations along the route. There are special operating rules to cover this for different commodities and in different areas.

When the lading is already cool as, for example, with apples out of cold storage which should be at a temperature of about 32 F, ventilating at 32 F is not only hazardous but harmful. There is not much reserve of heat in the load above the freezing point of the fruit and if the temperature outside falls, the fruit may freeze; if it rises above 32 F it will cause an undesirable rise in the temperature of the lading and cause the apples to ripen and favor the development of decay. Accordingly, in such cases it is better to forward the shipment with vents closed and plugs in to take advantage of the hold-over refrigeration in the load itself.

The only way a reliable ventilation service can be developed is to have cars equipped with thermometers to show the temperature inside the car as compared with that outside (Fig. 12). Refrigerator cars are thus equipped on the Canadian lines[11] but to date not on any of those in the United States.

Heater service. With shipments of perishables in refrigerator cars during the winter season or periods of very cold weather the problem is not only to prevent freezing damage but to avoid extended exposures of any part of the load to high temperatures that may result from operation of car heaters. Under actual operating conditions in non-fan cars it often happens that heater service provides temperatures throughout most of the load which during warmer weather would cause shippers to place the shipment under refrigeration (Fig. 11). This results from the impossibility of warming all parts of the load uniformly; in preventing freezing near the floor the heaters often produce undesirably high temperatures in the upper part of the load. In the United States car heaters are used under what is termed "Carrier's Protective Service against Cold" which is based on prevailing or anticipated weather conditions without regard to the temperature inside of the car. The rule for applying this service with charcoal heaters in the shipment of apples, for example, is to light the heater in the forward bunker when the outside temperature drops to 10 F and to light the heater in the rear bunker when the outside temperature drops to −5 F. They are extinguished in reverse order as outside temperatures rise to these same points.

There are two general kinds of **car heaters,** those burning charcoal for fuel and those burning liquid fuel, either alcohol or oil. The oil-burning heaters are used chiefly for preheating cars before loading, the others for providing heat during transit. They are used in the ice bunkers where they are accessible for servicing without the operator having to enter the loading space of the car. One type of thermostatically controlled alcohol heater embodies a very ingenious steam turbine

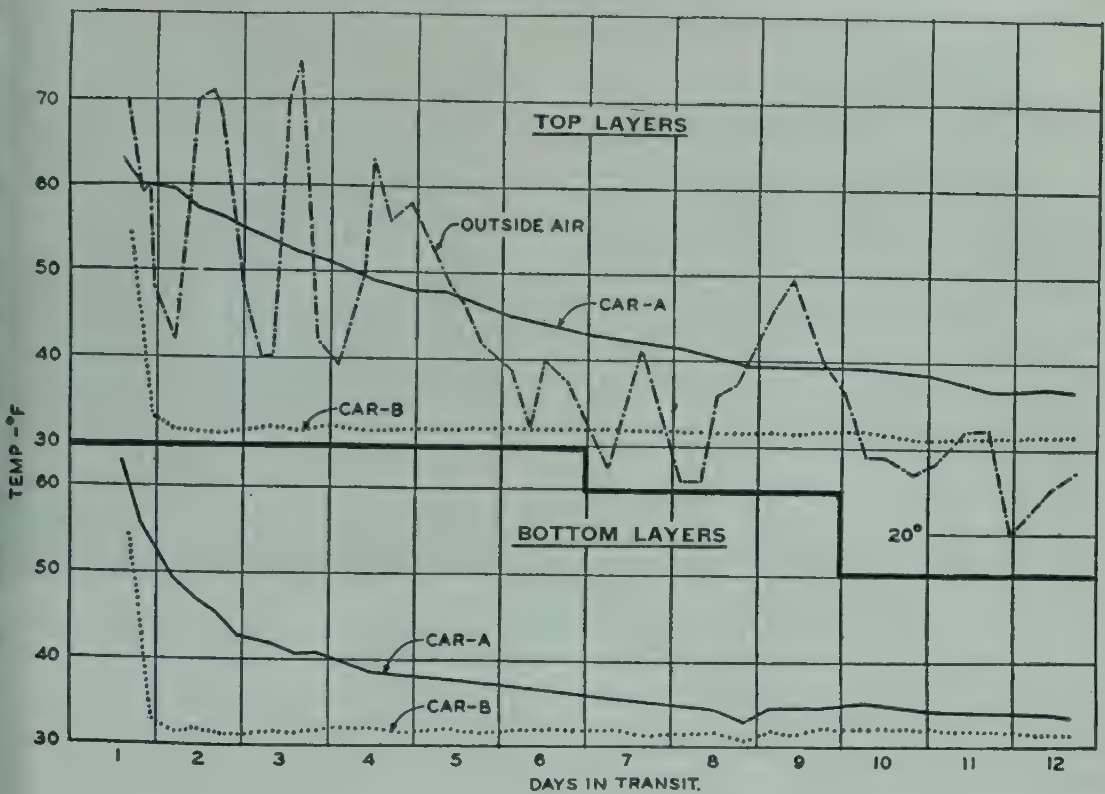

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Fig. 9. Outside Air Temperature and Average Temperature of Top and Bottom Layers of Lettuce in Transit from Brawley, California to New York City.

Car A. Standard refrigeration (bunker ice only). Car B. Package ice and top ice.

to force the heated air under the floor racks and warm the coldest part of the load where heat is most needed. Most of the thermostatically controlled alcohol heaters, however, depend on convection currents for circulating the heated air, as do the charcoal heaters, but the spread in temperature between top and bottom of the car is usually less with the former because of the automatic control. The charcoal heaters are manually operated for the most part and are manipulated only at regular inspection points.

On Canadian cars equipped with overhead ice bunkers the car heaters are slung underneath the car[11] and utilize charcoal or gas for fuel to heat an antifreeze solution circulated in coils placed under the floor racks. This arrangement puts heat where it is needed most and avoids excessive warming of the top of the load. Equipping these cars with indicating thermometers (Fig. 12) enables the heater service to be rendered upon the basis of the need for heat as indicated by the minimum temperature inside the car.

Fan Cars

Various types of fans have been tried, to provide better refrigeration through forced air circulation in the cars. The "Preco" fans have been the most successful and are now widely used. The **Preco system** consists of seven centrifugal fans mounted on a shaft under the floor racks at each end of the car. By attaching a $\frac{3}{4}$-hp electric motor or a portable gasoline engine to the drive shafts the fans can be used to precool the load before shipment, utilizing ice and salt in the bunkers to cool the air forced up through the mixture and delivered over the top of the load. During transit the fans are operated by a belt from friction driven wheels in contact with

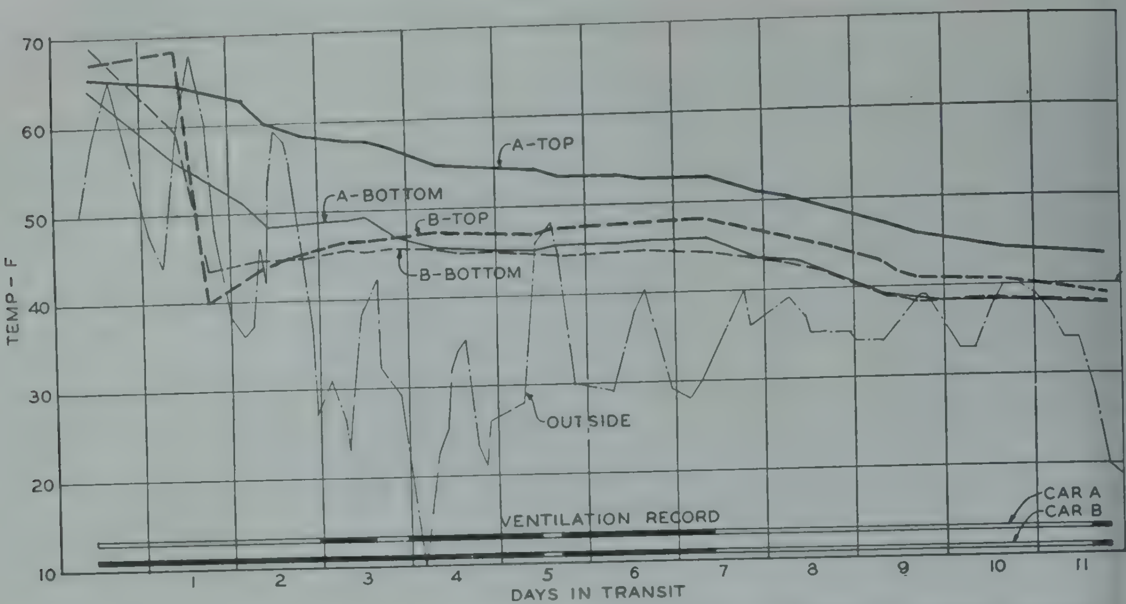

Fig. 10. Outside Temperature and Average Temperature of Top and Bottom Layers of Oranges in Transit from California to New York City.

Car A. 462 boxes, standard ventilation; Car B. 462 boxes precooled 8 hours; vents closed to Ogden Utah, standard ventilation beyond.

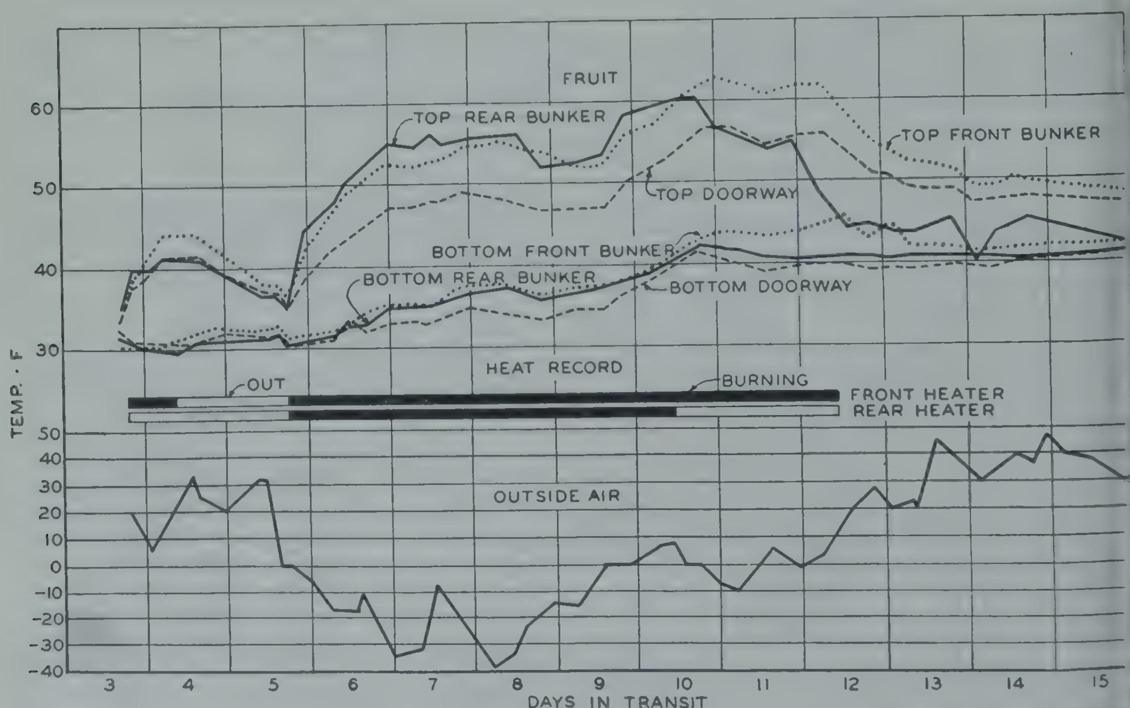

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Fig. 11. Temperatures of Apples in Transit in a Car Equipped with Standard Charcoal Heaters Operated According to Rules of Carrier's Protective Service, Showing Typical Results when Heaters Are Operated According to These Rules in Extremely Cold Weather.

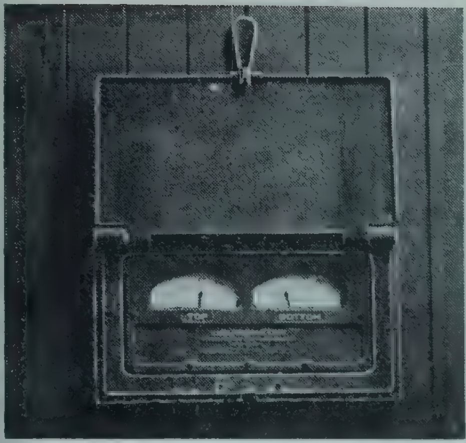


Fig. 12. Distant Reading Thermometers Installed on a Refrigerator Car; Showing Top and Bottom Air Temperatures Inside the Car 20 Minutes After the Door Was Opened for Unloading.

the car wheels, a coil spring being used to maintain the correct pressure between the two wheels. The fans operate only when the car is in motion and are so arranged as to force air up through the bunkers regardless of the direction the car is moved. The wheel and axle ratios are such that at 30 mph train speed the fan output is 3200 cu ft per min, and at 50 mph it is 7200 cu ft per min, which means, in terms of air turnover, about seven changes per minute. The advantages of the forced air circulation, in enabling a heavier load to be carried as well as in reducing the usual wide spread in temperature between top and bottom layers in a car, are shown in **Fig. 13.** These data show that the use of a fan-equipped car made it possible to ship a 50 percent heavier load with lower temperatures in the top layer than in a standard load in a non-fan car.

Fan cars are favored for use with shipments under heater service because of the uniformity of temperature they produce throughout the load in contrast to the stratification of temperatures usually found in cars without fans. The fans make it possible to avoid undesirably high temperatures at the top of the load and dangerously low temperatures at the bottom. Less heat is needed in fan cars than in non-fan cars to prevent freezing damage.

Overhead Bunker Cars

Most of the overhead bunker cars are used on Canadian lines. These cars differ from old type standard end bunker cars chiefly in the ice bunkers. These are usually

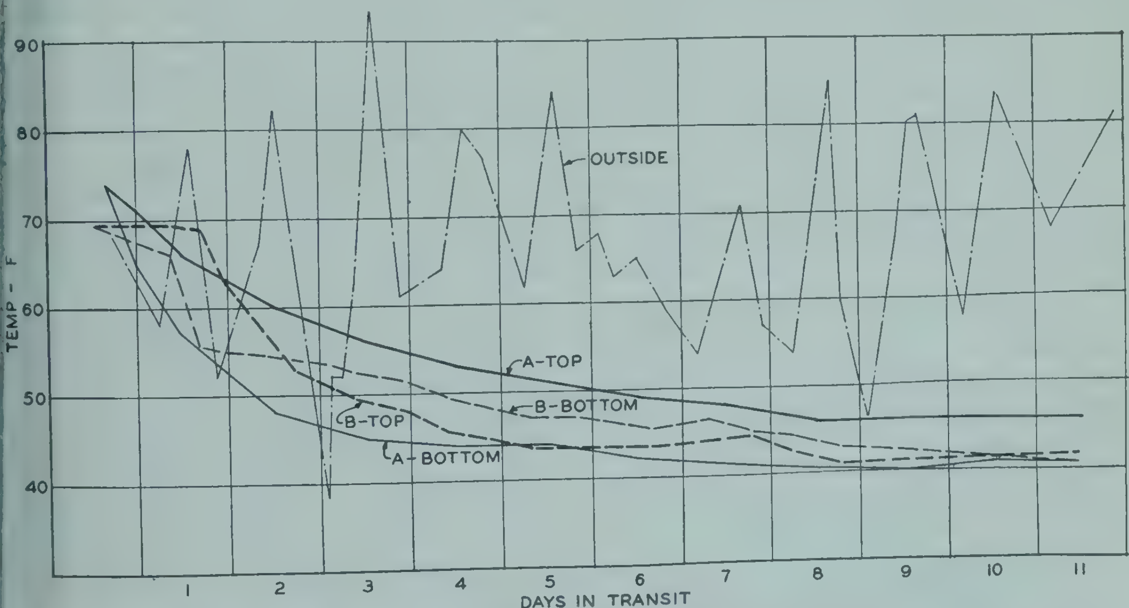
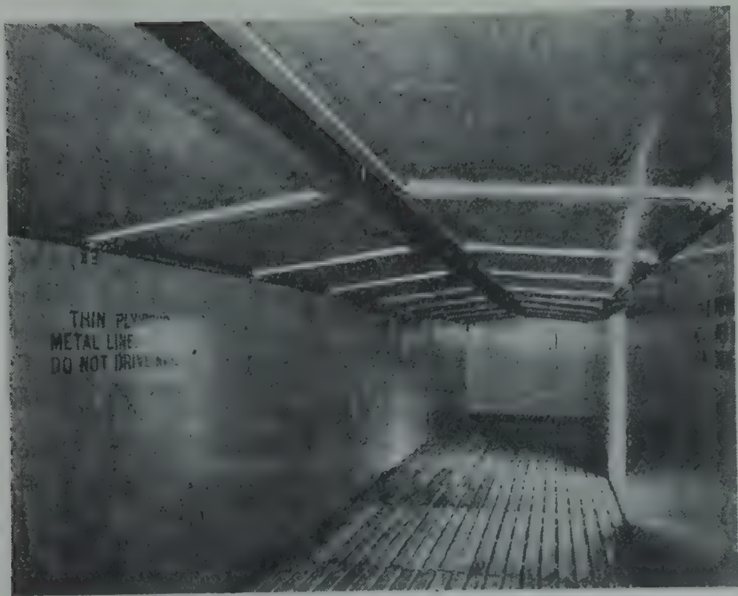


Fig. 13. Outside Temperature and Average Temperature of Top and Bottom Layers of Oranges in Transit from California to New York City.

Car A (no fans), 462 boxes; preiced, replenished after loading; reiced once in transit (Waynoka, Okla.). Car B (fan equipped), 692 boxes; preiced, replenished after loading; reiced once in transit (Belen, New Mexico).



Refrigerating Engineering

Fig. 14. Inside View of Overhead-Bunker Car Showing Underside of Tanks, Construction of Drip Pan and Floor Rack with Both Stringers and Slats Crosswise.

brine tanks to take a mixture of ice and salt but some are basket bunkers. There are eight of these comparatively shallow bunkers which are iced with crushed or coarse ice through the eight separate hatches in the roof of the car. Block ice and chunk ice are not used. The arrangement of the bunkers and baffles is such that the cooled air and drip water pass down at the sides, the drip water being caught by a gutter in the floor which leads to drain pipes in the ends. The warm air returns to the bunkers through a space in the overhead baffle along the centerline of the car (**Fig. 14**). Crosswise air circulation is facilitated by crosswise stringers and slats of the floor racks. For a detailed description of these cars see reference 12.

There are two outstanding advantages of this type of car over the standard end bunker car (without fans): (1) the increased loading space due to the removal of the bunkers from the ends of the car, and (2) the more uniform temperatures obtainable from the location of the bunkers over the top of the load. There are likewise two principal disadvantages: (1) increased costs, and (2) the necessity for icing eight bunkers instead of two, and using crushed ice, with the resultant difficulty in icing at stations not equipped to furnish crushed ice. (This includes most icing stations on United States lines. Canadian lines which are thus equipped report that icing can be done more expeditiously with crushed ice than with ordinary chunk ice.)

Overhead bunker cars have met with considerable favor in the transportation of **frozen products.** Maintenance of these products at temperature levels considerably below their actual freezing points is essential to the preservation of acceptable market quality. In shipping frozen peas, for example, it is important to keep the commodity temperature from rising above 20 F in order to hold the peas in a hard frozen condition so that they will not stick together. The comparative performance of the two kinds of cars in the shipment of frozen strawberries, asparagus, rhubarb, and spinach from Hillsboro, Ore., to Jersey City, N. J., is shown in **Fig. 15.** Both cars were heavily insulated, having 6 in. or more of insulation in roof, side walls, and floor, and were generally comparable except for the ice bunkers. While both the end bunker and overhead bunker cars carried the commodities satisfactorily, it will be noted that the best temperatures were in the overhead bunker car and were secured with 20 percent of salt, whereas 30 percent of salt was used in the end bunker car.

Brine Tank Cars

Brine tank refrigerator cars are largely

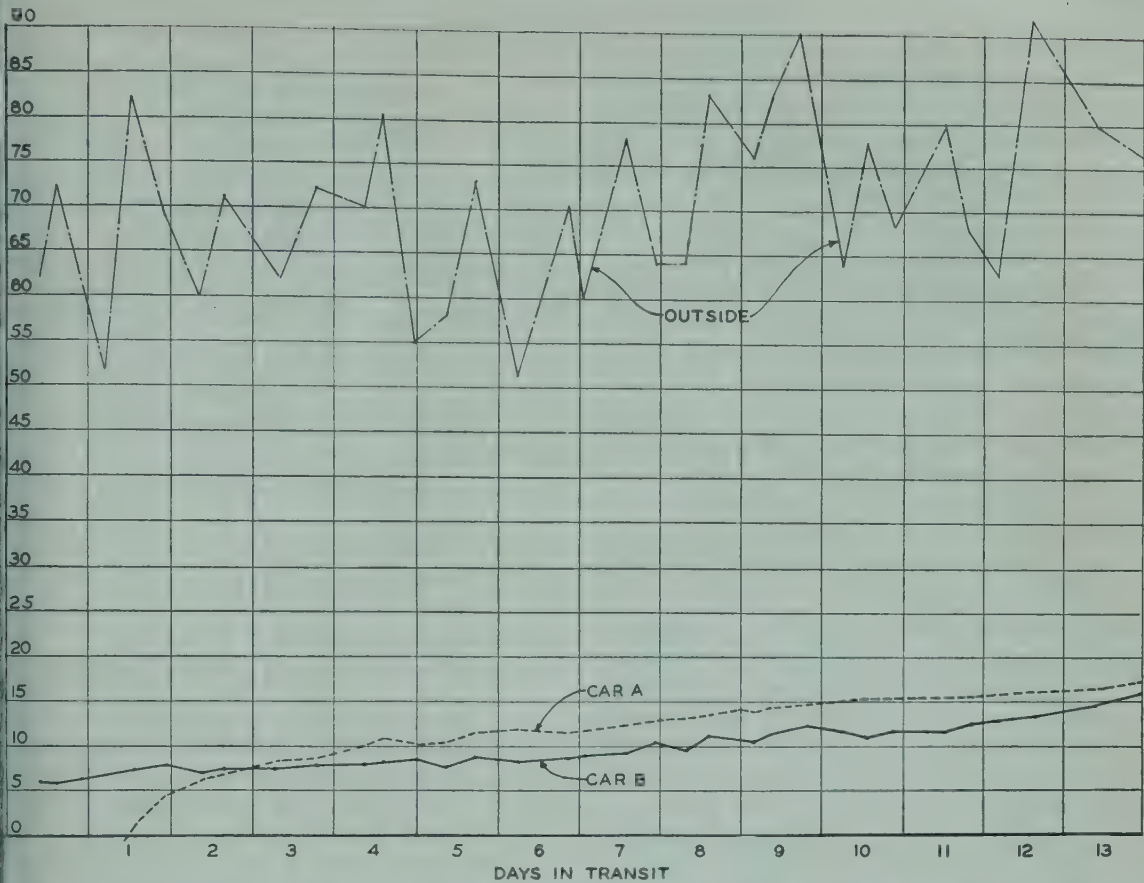


Fig. 15. Temperatures in Transit of Frozen Strawberries in Top Layers (Average of 3 Positions) During Transit from Hillsboro, Oregon to Jersey City, N. J., July 12–26, 1943.

Car A. Standard non-fan end bunker car, 30% salt; Car B. Overhead bunker car, 20% salt.

Total ice used	Car A—19,367 lb
	B—30,054 lb
Total salt used	A— 8,236 lb
	B— 7,180 lb

used for shipment of fresh meat and other packing-house products, fish, poultry, eggs, butter, cheese, oleomargarine, and other non-living products which do not produce "vital" heat to increase the cooling requirements, in contrast to such things as fresh fruits and vegetables which, being alive and continuing to respire and carry on other vital processes after harvest, produce considerable quantities of heat that increase the refrigeration load during transit. Most of the brine-tank cars are owned or leased by the shippers who pay for the ice and salt supplied by the carriers. There are several different arrangements of the ice tanks. For the most part, however, these tanks are located in the ends of the cars and are equipped with valves by which they can be drained when it is desired to replenish the ice and salt.

While the temperatures produced in these cars are ordinarily adequate for the products carried, the brine tank cars in general do not provide as low temperatures as the basket bunker cars previously described.

Mechanical Refrigeration of Freight Cars

Considerable work has been done in attempting to perfect a practicable system of mechanical refrigeration for freight cars. Some of these attempts have been with absorption systems of cooling which have provided automatic operation, others have employed compressors driven by manually

controlled Diesel engines, automatically controlled gasoline engines or other sources of power. However, none of these applications has thus far proved practical under the conditions surrounding the use of railroad refrigerator cars.

Importance of Precooling

As applied to shipments of perishables, precooling means the rapid removal of heat from car or commodity, or both before shipment, to or below the range of temperature that they might ultimately attain as a result of refrigeration in transit. Precooling is important from two standpoints: (1) it reduces the ice requirement during the transit period, and (2) by quickly reducing the commodity temperature it arrests ripening and the progress or onset of fungous decays, thus insuring better carrying quality and improved market condition at destination. What this means for commodities such as Bartlett pears, which are often held in storage after arrival at destination, is readily apparent when it is considered that if carried at an average temperature of about 40 F during the 10 or 12 days in transit from California or the Pacific Northwest to Atlantic seaboard markets, these pears can be stored satisfactorily for as long as two months after arrival, whereas if their transit temperature is as high as 50 F they will ordinarily have to be marketed and consumed immediately after arrival.[2]

How to Utilize Refrigerator Cars to Secure Maximum Protection of the Load

A. **In refrigeration service:**
   1. See that drains are clear.
   2. Use cars preiced before loading.
   3. Keep doors closed except during loading.
   4. Load cars through an enclosed canvas tunnel or hang a canvas flap over the doorway to prevent free passage of warm air into the car.
   5. Stow the load properly and brace it well.
      a. With fresh produce, space so as to provide opportunity for air circulation around individual packages, and brace well to prevent shifting in transit.
      b. With frozen produce, provide wall racks or flues to keep packages away from car walls. Stow packages tightly together so as to reduce air circulation around individual containers and preserve as much as possible the refrigeration already present in the consignment.
   6. Segregate lots by maturity and place each in that part of car where prevailing temperature level can be utilized to best advantage. With California cantaloupes, for example, the most mature or "full slip" melons should be loaded in the coldest location; the least mature or "half slips" should be loaded in the warmest part of the car, i.e., the top layer.[9]
   7. Use car fans when available.

B. **In ventilation service:**
   1. See that all air channels are clear; i.e., plugs out, hatches properly adjusted, and bunker openings unobstructed.
   2. See that waybill is properly endorsed with desired instructions as to ventilation service desired; i.e., "Close vents at 32 F," or "Vents closed to Potomac Yard. Standard ventilation Potomac Yard to destination."

C. **In heater service:**
   1. See that drains are plugged and that doors, hatches, and plugs, fit tightly.
   2. Preheat cars before loading.
   3. Keep doors closed except during loading.
   4. Load cars through canvas tunnel or flap-covered doorway.
   5. Space packages away from contact with walls of car.
   6. Use car fans when available.

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If you searched this chapter for something which was not found in it, please let the editors know.

23. CARGO REFRIGERATION ON SHIPBOARD

General

THE refrigeration industry owes a great debt to the steamship. This process we call mechanical refrigeration and which we now take so much for granted in our daily life, had its beginning on shipboard. It, like so many of our great inventions, was born of necessity—in this case, British dietary necessity. The tight little Isle, unable to produce a sufficiency of the essential food, sought ways and means to import frozen meat from the great open spaces of Australia. Refrigeration's twin barriers of time and heat were represented by great distances and tropic sea, they standing resistingly between the source and the consumer. In the summer of 1880, after seven years of costly trial and error, the steamer "*Strathleven*" brought to England the first successfully carried refrigerated cargo. The trials began with ether systems but success came and was maintained for many years with dense-air machines. Progressive developments in marine refrigeration employed carbon dioxide and annhydrous ammonia as refrigerants. Shipping being a highly practical industry, it was in earlier times prone to develop along strictly practical channels, and in so doing lost leadership in refrigeration to the shoreside industries who eagerly and scientifically applied it to all manner of services. So hidden is the record that few today realize the part shipping played in this vital refrigeration industry.

L. L. WESTLING, Author Chapter 23. Born in Fairbury, Nebraska. Educated at Univ. of Nebraska. Formerly, Engineering Draftsman and Chief Draftsman in various west coast shipyards, 1916–21; Assistant Supt. Engr., Asst. to Engrg. Manager, Technical Engineer, Refrigerating Engineer, Matson Navigation Company.

Author of numerous articles on engineering and technical aspects of marine refrigeration; ADS-43, "Handling and Stowage of Ship's Perishable Cargoes."

Member, Society for Naval Architects and Marine Engineers; Amer. Soc. of Refrigerating Engineers—Chairman, San Francisco Section, 1948–49; Director, 1949–52; member of committees on "Refrigerated Transport, Marine," ASRE Standard 26, "Recommended Practice for Mechanical Refrign. Installations on Shipboard"; California Registered Professional Engineer, M.E.

At present, Refrigeration Engineer, Matson Navigation Company, San Francisco, Calif.

Only in relatively recent years, with the growing costs of imperfect deliveries of perishables, the discovery of the halide refrigerants and the war-time demands for non-hazardous refrigerants, has the marine applications seen renewed scientific progress. This development, primarily American, has covered all phases of marine applications; it has come simultaneously with improvement in shoreside facilities and with a marked reduction in that first barrier, time, through the much increased speeds of modern ships of all classifications.

Present day marine applications of refrigeration embrace air conditioning, ice making, the chilling and freezing of fish catches, the processing of sea foods, the keeping of perishable stores, and the transportation of refrigerated cargoes. The first five mentioned are highly specialized or have been adequately described in other literature and will not be treated in these pages. The sixth, that of the movement of perishable cargoes, and the means by which they are transported, will be the subject of this chapter. The following pages will include considerable basic data, inasmuch as there are many considerations peculiar to the application which will not be found in the general basic data printed elsewhere.

Refrigerator Arrangements and Utility

The location and arrangement of the compartments within the hull, as well as the subdivision of the insulated enclosures, should reflect, if possible, the trade in which the vessel will serve. The volume of

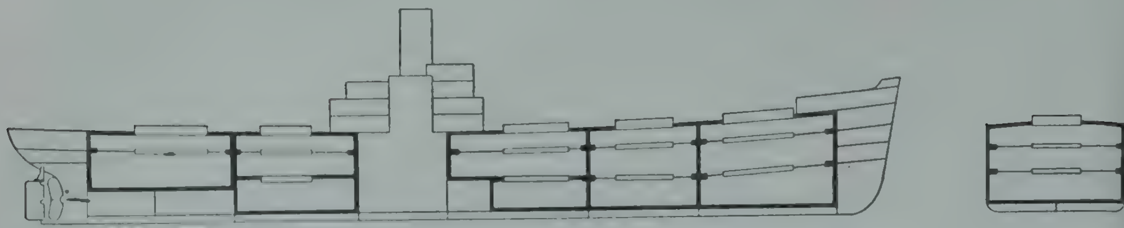


Fig. 1. Typical Arrangement of the All-Refrigerated Ship.

trade, the scheduling of ports of call, and the efficient and speedy handling of produce with minimum exposures, are all factors that will influence these arrangements.

In our race against time between harvest, processing or storage and delivery at destination, the arrangement should allow perishables to be the last cargo loaded and the first to be discharged.

Limitations of dimension and arrangement will be found in the ship's structure, in the compliance with floodability compartmentation of the hull, and in the extreme fire-resistant regulations to which American ships are singularly subject.

No vessel should be insulated or outfitted for an exclusively cold water route for almost certainly the vessel will in some future time or service move through warm waters. The resulting warm water reserve capacities in cold water services will prove of good return during the vessel's normal useful life.

The refrigerators should not be designed for high temperature cargo services only, unless there is a certainty that the vessel will always remain in that limited trade. Otherwise, all compartments should be readily convertable to any temperature service between subzero and 55 F, the resulting flexibility in the segregation of cargoes by temperature requirements or by ports of call being highly desirable.

In a vessel only a portion of which is refrigerated and designed to permit late loading and early discharge, the compartments will usually be located under the topmost deck to the hull. Further considerations will be given by the naval architect relative to the effect on trim of the vessel in normal loading conditions. Generally speaking the added weights of the insulation and the perishable cargo will not be as influential as would be the weight of dry cargoes which are usually of greater density. Often these compartments will be empty or light loaded during some legs of the voyage. Trim conditions will generally require that the refrigerators be placed forward of the mid length of the vessel, or grouped about the middle section where the moment arms for trim are of lesser consequence. Almost without exception the refrigerators are arranged symmetrically about the ship's longitudinal centerline.

The rooms or areas where the refrigerating control values are installed should be so located and arranged that the apparatus or controls are accessible through trunks or passageways to the operating

Fig. 2. Typical Arrangement of Combination Refrigerator and Dry Cargo Ship. Insulated Compartments in Upper 'Tween Decks.

personnel at all times. When the boundary bulkheads parallel hatches, they should clear the openings by 3 feet as a safety measure, providing adequate room for handling hatch beams and covers.

The greater the number of subdivisions in the refrigerated compartments, the greater the loss to the ship's revenue spaces. This is due to the volumes occupied by the insulated partitions, the cooling apparatus, insulated piping and access areas. On this basis the all-refrigerated ship with main structural boundaries insulated only, would make for the most efficient use of a ship's costly enclosures. On the other hand, the conventional all-refrigerated ship with insulated hatch plugs at the weather deck, has several undesirable features. The difficulty of providing uniform compartment temperatures and of refrigerating the hatch areas remote from the refrigeration apparatus is recognized. With large volume rooms, the extended period in which the hatch is open to the outside atmosphere for loading and discharge is not conducive to providing good environment for frozen or fresh cargoes at this critical interval in their keeping lives. Seldom are frozen goods sufficiently subcooled to contribute adequate self-refrigeration during the extended interval of loading. Fresh products are not generally pre-cooled before loading and the accumulation of respiratory heat in the compartment and its delayed extraction is obviously detrimental. During long discharge intervals in ports, much atmospheric moisture is driven into the hold to cause "sweating" or frosting of products, some of which may suffer from this exposure. With partial delivery at a port of call, such an exposure may unfavorably affect the remaining cargo. The problem is otherwise without solution because of the harbor workers' refusal to work in the spaces with the refrigerating equipment in operation.

A more suitable arrangement of the all-refrigerated ship can be had by having the insulated compartments in the 'tween decks fitted with access doors in hatch-line bulkheads, and with the various combinations of insulated plug hatches at the lower hold and 'tween deck levels. Hatch areas may be used for general cargo or treated as separately refrigerated compartments. Many ships are fitted with side port doors at the 'tween deck level, through which cargo is handled by conveyors, independent of the ship's over-all cargo gear.

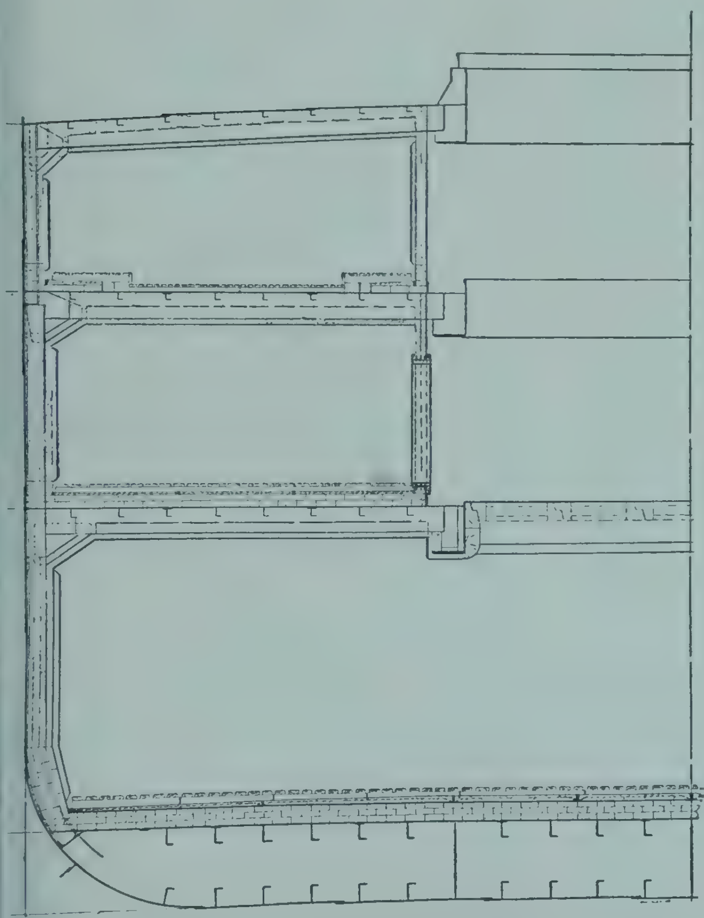


Fig. 3. Typical Midship Section of All-Refrigerated Ship.

The central refrigeration machinery plant whenever possible should be located in, or immediately adjacent to, the main propulsion machinery room where the ship's responsible watch officers are in constant attendance. With the nomadic tend-

encies of unlicensed sea-going personnel who attend refrigerating equipment, close supervision by the engineer officers is essential. A central location of the refrigeration machinery usually results in economy of space and close connections for power and pumping facilities.

The observance of the above factors and limitations will guide the draftsman's hand to form the outline of the most suitable arrangement for the ship and the intended trade.

Insulation

Composite insulation is often erroneously defined simply as a heat barrier. Describing an equally important function, the definition should include the property of the moisture-vapor barrier.

Low temperature insulating materials in themselves depend principally upon the voids or air-filled interstices for their efficiency in resisting the transmission of unwanted heat to surfaces and spaces. The substance of the envelopes or solids confining the air cells contribute but little resistance, and these elements, various properties of heat transmission, their dimension and physical form, are the principal factors that cause variations in the comparative values of heat transmitting coefficients.

There is a wide variation in the moisture-vapor resistance of insulators and while the individual fiber or elements may be, and usually are, inherently non-hygroscopic, the interstices of an air-permeable insulator may hold in capillary suspension, water from condensation of air-borne moisture, or free water from other sources. However, if permeable insulators can be sealed or shielded from all sources of moisture, it can borrow the property of moisture resistances from the seal. Assuming that moisture seals can be perfect, it allows a wide selection of insulating materials.

Moisture-vapor and water resistance is of particularly great importance on board ship because of frequent and extreme temperature cycles through intermittent refrigeration. Upon termination of refrigeration at discharging ports, there is always a period in which the body or concealed mass of insulation will be at lower temperature than the open room, and often the room surfaces stand dripping wet with atmospheric moisture which gains entrance through the open door or hatch. It is clear from this that in addition to the moisture seals on the warm side, the cold side should be equally well moisture-sealed and that the installation of cold side "breather ports" are fallacious. Other common sources of water in ships' refrigerators are from melting of ice packed with vegetables and from the defrosting of cooling surfaces.

There are numerous block-type insulators, made of organic and inorganic materials. Some are very rigid and when used should be of small dimension blocks set in a cement that will remain pliant at all temperatures, the cement to provide the necessary flexibility. Some block insulators being fibrous are permeable and the blocks are coated with moisture resistant materials. The seal should be preserved after working or cutting by application of a suitable coating over the raw surfaces. There are block and blanket insulators made of fibre without benefit of seals and which depend upon the vapor seal of the assembled wall or surface to prevent the ingress of moisture.

Fibrous insulators have been used extensively in war-time ship construction. This class of material is generally fire-resistant but in the majority of cases this quality has been voided by the use of wood structure intended to supply loading strength which the insulator does not have in itself. Steel internal structure is sometimes used to assume these loads but at considerably higher cost than the wood assembly.

Most fibrous insulators are air-permeable but when installed behind continuous and perfect moisture-vapor seals they can give very creditable service. There are few insulators which inherently have both of the properties of heat and moisture barriers.

Corkboard remains the favored insulating material of many designers and operators. It has many virtues as a ship insulator, including structural strength and fire-resistant properties. It has good moisture-resistant characteristics, is relatively im-

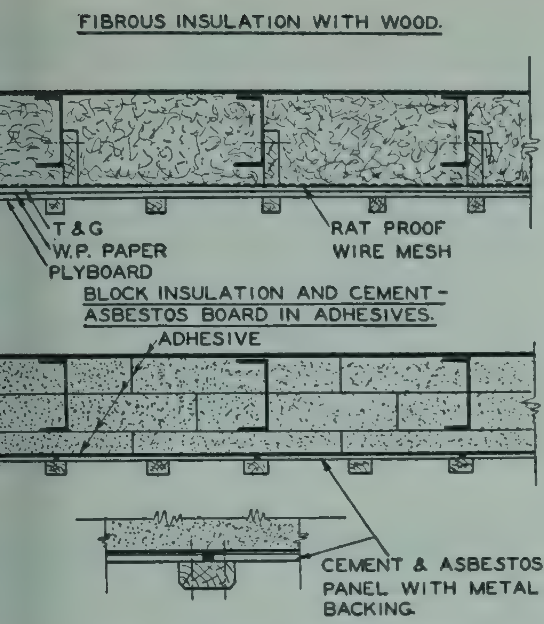


Fig. 4. Typical Longitudinal Sections—Ship's Side (2 deg).

permeable and is durable. Being a very old product it has been well time-tested.

Granulated or powdered insulators, while being capable of adjustment to flexing, are subject to packing, settling, or shifting, and some are flammable. This type of material is not suitable for shipboard use.

But little is known of the effectiveness and durability of laminated metallic or reflective type insulators on board ship and being new, they have yet to prove their worth in long periods of service.

The insulators for ship's refrigerators should have all the properties required by shoreside installations, but several of these properties are of magnified importance in the marine application. Severe service conditions which subject the insulation to injury or change by mechanical damage or vibration as well as intermittent refrigeration, places exacting requirements upon the composite design.

The ideal insulating material has not been found and the degree to which the various insulators approach the ideal must be measured by the user, designer, or owner. It is a very controversial subject. The ideal shipboard composite insulation should have the following characteristics:

1. High insulating value
2. Impervious to moisture from any source
3. Light in weight
4. Flexible and resilient to accommodate ships' stresses and loading
5. Good structural strength
6. Resistant to infiltrating air
7. Resistant to disintegration or deterioration
8. Fire resistant or fire-proof
9. Odorless
10. Not conducive to harboring rodents or vermin
11. Reasonable installed cost
12. Workable in construction.

Encumbering requirements have been placed upon American owned ships by government regulation and the properties of the insulator and the details of construction must meet exacting approval of the U. S. Coast Guard and the U. S. Public Health Service.

Refrigeration Construction

There are three principal parts to the marine refrigerator boundary: The envelope or basic structure, the insulating material and the room lining.

The envelope is usually composed in part, of the ship's hull, the water-tight decks or the main water-tight bulkheads, which members obviously give effective resistance to the ingress of moisture-vapor from the warm side. The inboard boundaries outlying the refrigerators should have equal ability to resist moisture, a fact which is seldom appreciated and too often neglected. A continuous steel bulkhead with lap seams and welded stiffeners provides a boundary of adequate strength and tightness. Details of design may accommodate dimensioned insulators or facilitate means of fastening these materials. Doorway main bucks of steel channel provide good structure, but is usually a source of warm side sweating on low temperature rooms because of the heat gain through the metal conductor. Wooden door bucks minimize sweating but are a retreat from our efforts to eliminate concealed wooden structure.

Partitional bulkheads may be of similar detail, but air-tight sealing is of less importance. Some installations are framed with angle-bar grids only, between which the insulator is installed. In passenger ves-

sels (over 12 passengers) the Coast Guard Regulations governing fire-resistant construction are severe, and wood assembly is restricted. Under no circumstances of any kind should wood be a part of the floor assembly, because of its rapid deterioration under the prevalent conditions. Asbestos wood or phenolic block, while dense, will give more satisfactory results than wood.

The assembled boundary of a ship's refrigerator must be able to withstand heavy floor loads and also severe wall thrusts of cargo when the vessel rolls or pitches in a heavy sea; it must be able to flex with the hull structure being stressed in any angle of the three dimensions. The assembly must resist change by forces occasioned by vibrations caused by the propelling machinery or the sea, and by the careless or accidental handling of cargo by stevedores. The moisture-vapor seal of all surfaces must be preserved under all of these conditions.

The means by which the various types and kinds of insulators are held in position are numerous. Fibrous battings are secured to steel work with welding studs or cemented fasteners. Packing type insulators are stuffed into spaces formed by two room-lining surfaces or between linings and the ship's structure. The most satisfactory means to secure block insulators is to apply a complete envelope of adhesives after cutting and fitting. Heated asphalt supplemented by skewers has been used to a great extent but that method is now sharing the job in increasing volume with the various formula adhesives, most of which are in part or wholly of latex or rubber bases.

Adhesives when properly applied to the total area of each piece of fitted block not only adequately secures the material but at one and the same time provides a continuous and multiple moisture-vapor seal. Steel boundary bulkheads may be of non-air tight construction with this type of installation, the cement effectively closing off all openings through which moisture-laden air could otherwise migrate. If the block is resiliant and of structural strength, no furring or internal strength frame work is required. Needless to say the cements should contain no materials or vehicles which will give off tainting odors that will not have been dissipated before the refrigerators are placed in service. The methods by which adhesives are applied should be prescribed by the manufacturer and his instructions strictly followed. As with all applications of insulation, the concealed steel structure of the vessel should be properly prepared to preserve the metal and to insure good adhesion of all coatings. The use of adhesive cements for marine refrigerators has been tested over an extended period and has proven to be a practical method.

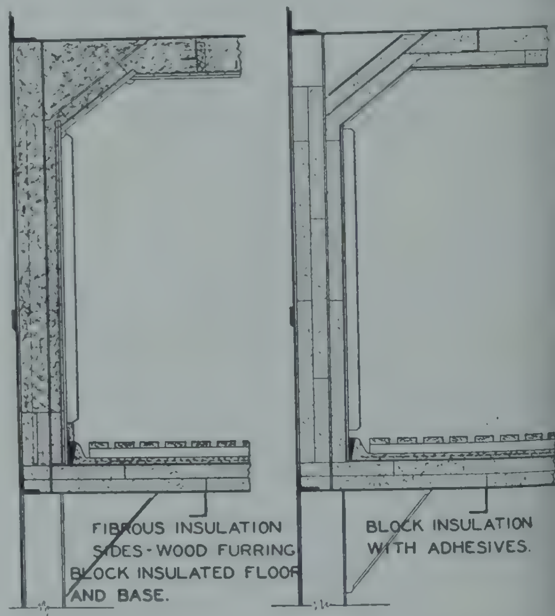


Fig. 5. Typical Transverse Sections at Ship's Side.

The conductivity of the various insulations are published elsewhere in the Data Book, and need not be reviewed. There is not sufficient difference in their effectiveness, however, to eclipse the importance of their other properties in marine applications.

Only in extreme cases should there be concealed voids in the insulation assembly. It will be found more effective and of less cost to fill such volumes with insulating material than to construct internal framing. The exceptions to the rule will be in the deep volumes formed by bilge brackets, deck brackets, and open-box type girders. Solid filling results in more insulation thickness than is needed for a heat bar-

rier in the overhead in way of the beams and at the ship's side where the frames are deep, a good fault. Voids can provide a refuge and home for vermin or rodents, and atmospheric changes within the space may develop conditions detrimental to the protection of the ship's steel structure.

The third part of the boundary assembly is the room lining. This surface must be of sturdy construction to withstand the impacts of frequent loading and handling of cargo. On passenger vessels the Coast Guard regulations require that the lining be fire-resistant. The age-old use of tongue-

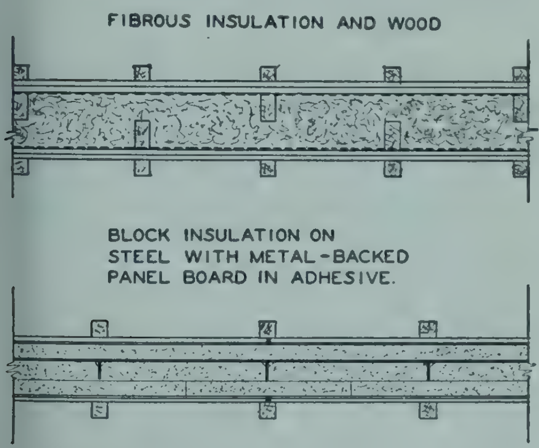


Fig. 6. Detail Wall Sections—Various Types.

and-groove lumber is now considered obsolete for any type of ship and various kinds of lining are employed. On freight vessels where wood is permissible, plyboard made with water-proof glues is usually applied. A few installations have been made of Micarta sheets and of Masonite, both satisfactory when properly supported.

On passenger vessels a favored lining is made of cement-and-asbestos hard board and installations made of this material in 1937 and since have proven the durability of the material when supported by block type insulators. Steel linings have been used on occasion, but installation costs, difficult maintenance and ship repair problems and slow assembly of closely fitted welded plates will not make the method popular.

The U. S. Public Health Service, in order to discourage Arctic-minded rats have insisted upon all linings being rat-proofed, including the durable cement-asbestos panel. Earlier installations had the panels backed with $\frac{1}{4}''\times16$ G. wire mesh for protection from rodents while newer installations are using cement-asbestos panels laminated with aluminum or steel bonded by the manufacturer.

In the application of panels with adhesives over block insulators, the butted joints should be separated sufficiently for the adhesive to extrude and provide a moisture sealed joint and to accommodate movement of the panels by the flexing of the ship's structure. The joints may be covered by cargo battens, also secured by adhesive and with brass screws. The walls of all refrigerators should be fitted with vertical cargo battens which in the case of the cement-asbestos panel, may serve dual purposes. Battens on the walls should be on 15 to 18 inch centers to hold the cargo clear of the insulated wall. This serves to permit circulation of air and to prevent the contacting package from assuming the part of a room insulator.

The greatest weakness in ship refrigerator construction is the floor covering. Research and practice has not brought forth a totally satisfactory covering. Unlike the warehouse, the tightly packed cargo refrigerator must have floor gratings to insure the circulation of air and to protect the bottom tier of products from the leakage heat. The bearers of the gratings carry the weight of cargo to concentrated load areas of the floor. The room may be filled with warm general cargo in alternate service and a thermo-plastic covering may be damaged through penetration by the bearers. Contrarily, the floor covering must be elastic and flexible enough to accommodate changes from the flexing of a ship, or from extreme temperature changes, as well as maintaining a moisture-proof cover over the insulation under all conditions. Obviously, the traditionally used thermo-plastic bitumastic is unsuitable. In the other extreme the use of a rigid reinforced concrete slab has its limitations. Perhaps the most satisfactory material is a mastic composed of emulsified asphalt, sand and cement. This material is applied cold and upon setting has good load bearing qualities and is impervious to water. It has a small degree of ductility and may

be used in less thickness than concrete. It should always be reinforced and there should be expansion joints to accommodate set shrinkage and adjustment to movements of the ship's structure.

All rigid or semi-rigid floor coverings should have expansion joints of rubberbase composition capable of making good bond to the edges of the floor slabs or wall and not subject to shrinking by the loss of its vehicle through evaporation or in chemical change. The pattern of the expansion joints should trace the entire periphery of the room, the line of all under-deck girder systems, bulkhead offsets to pillars and similar lines of anticipated ship stress.

The melting of ice from ice-packed vegetables and the defrosting of cooling apparatus subjects the floor covering to much water. Unless the floor covering is permanently impervious to water in the slab, as well as at the joints, the floor insulation will be wetted, which in turn will deteriorate, lose its efficiency as an insulator, or give off odors. Upon freezing, it would lift the deck covering and cause its destruction. If the water penetrates to the steel, the ship's structure will corrode unnoticed until the perforated deck adds insult to injury.

It is asking much to provide a floor covering that will not develop faults through cracking or damage throughout the ship's life. As a secondary security against ingress of water, a membrane should be laid between the insulator and the floor covering. Historically the sweated-joint pan of eight pound lead has been used, but in an effort to conserve an essential material and save cost, the pan was often substituted with lead flashing only. The flashing is unsatisfactory as a protection and the lead pan will do nothing that a saturated felt membrane will not do at a great saving in cost and weight. A saturated asbestos felt laid in an adhesive is good design. The membrane need not be flashed to the wall if suitable sealing expansion joints are fitted at the juncture of the wall panel and the floor covering.

The need of a vapor-seal is of equal importance to the walls and ceiling as it is to the floor. The penetrating, searching

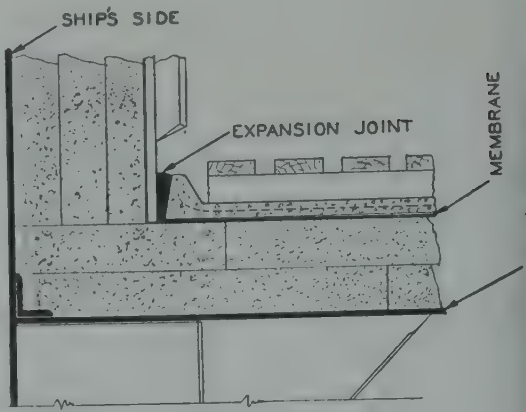


Fig. 7. Detail Floor Sections.

force of vapor pressure is little understood or appreciated. Its magnitude is made clear in other chapters of the Data Books. The migration of moisture into a permeable insulation can under certain circumstances cause wetting by the deposit of condensed vapor, frosting, and general deterioration of physical properties and efficiency of the insulator. When an attempt is made to provide a seal with water-proof paper, it should be applied in double thickness and the laps and perforations cement-sealed. The attachment of wall and ceiling panels with suitable adhesives precludes the need of water-proof paper inner linings.

While the floor is the weakest point in the ship's refrigerator, the weakest element in the floor is at the floor drain or scupper. This is a minor item of major importance. The weakness comes with the difficulty in bonding the top floor covering with the metal drain fitting and water will often find its way between the covering and the insulation. The conventional floor drain is fitted with a perforated plate flush with the floor covering and hidden by the floor gratings. Out of sight is out of mind and if the perforations become clogged by debris, it will permit water accumulation at the scupper. A drain fitting near a wall or corner will on most occasions provide a weak section in the floor covering and cracks will develop, running to the wall or across the corner. A satisfactory scupper fitting is illustrated herewith. It has the features of being flush with the top of the gratings, a lift-out cover for easy cleaning

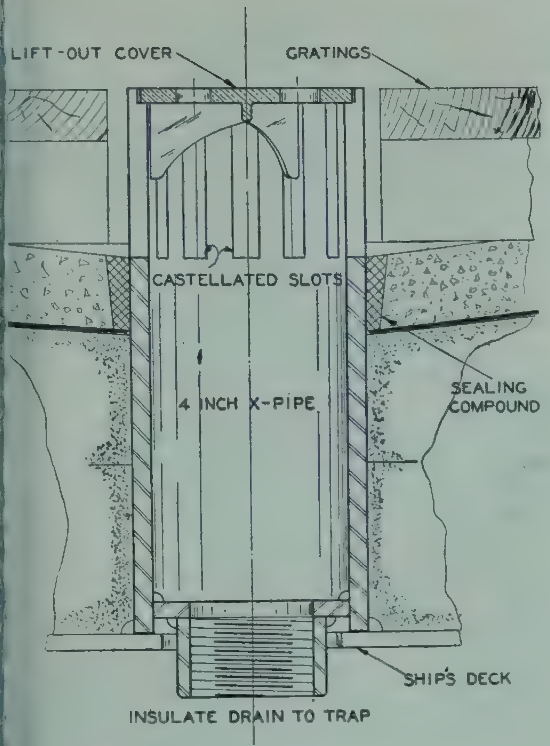


Fig. 8. Floor Drain Fitting.

and is bonded to the floor covering with expansion joint material.

There will be as many refrigerator designs as there are designers, each having their convictions in choice of materials and methods. It cannot be hoped that every condition can be treated in this chapter, but if the described fundamentals are considered and the known weaknesses are avoided, a creditable design should be forthcoming.

Refrigerator doors are generally a satisfactorily manufactured product and but little need be written on the subject. They should have generously designed hardware of steel, the doors and door frames should be metal sheathed, have a flat sill and double gasket. Very large or double doors should have additional "dogs" to insure proper sealing when closed.

In finishing, wooden surfaces should be varnished, not shellacked, the latter material having little protective penetration. Manufactured non-metallic surfaced materials may be painted or varnished but if non-hygroscopic, their original surface will usually present good appearance longer than a painted coating. Cement and asbestos panelling should not be shellacked but remain uncoated or may be waxed.

In the matter of insulating low temperature apparatus or piping, it is recommended that critical inspection should be made during the installation of this covering. All joints and surfaces should have total and generous sealing to prevent the ingress of atmospheric moisture to any surface where water may condense as "sweat" or form frost. Special attention should be given at pipe covering termini, at valves and bulkhead penetrations. On sub-zero services special composition adhesives should be used. The smallest omission or breach of a seal will signal the beginning of progressive destruction of the covering.

On shipboard where piping systems are relatively short the function of the insulation is more that of preventing the sweating or frosting of cold surfaces than it is to prevent heat gain, a factor quite generally overlooked.

Refrigerants

As indicated above, the marine refrigeration plant has successively progressed with the uses of dense air, carbon dioxide and anhydrous ammonia. Subsequently, the halide refrigerants have been widely used, particularly Freon-12 in reciprocating compressors and Freon-11 in centrifugal units.

Practical and regulative considerations and limitations have narrowed the selections to the latent heat, non-inflammable refrigerants with preference given to the non-toxic Freons.

Freon-22 has temperature-pressure characteristics similar to ammonia, but it is not recommended that it be used with evaporator temperatures above −20 F because of the critical oil miscibility properties above that level. Except for specialized marine services, this refrigerant would not meet requirements.

American designers have unanimously rejected carbon dioxide systems because of design pressures and weights of equipment and because of its low critical temperature. It must be conceded that ammonia is still our best refrigerant in its over-all

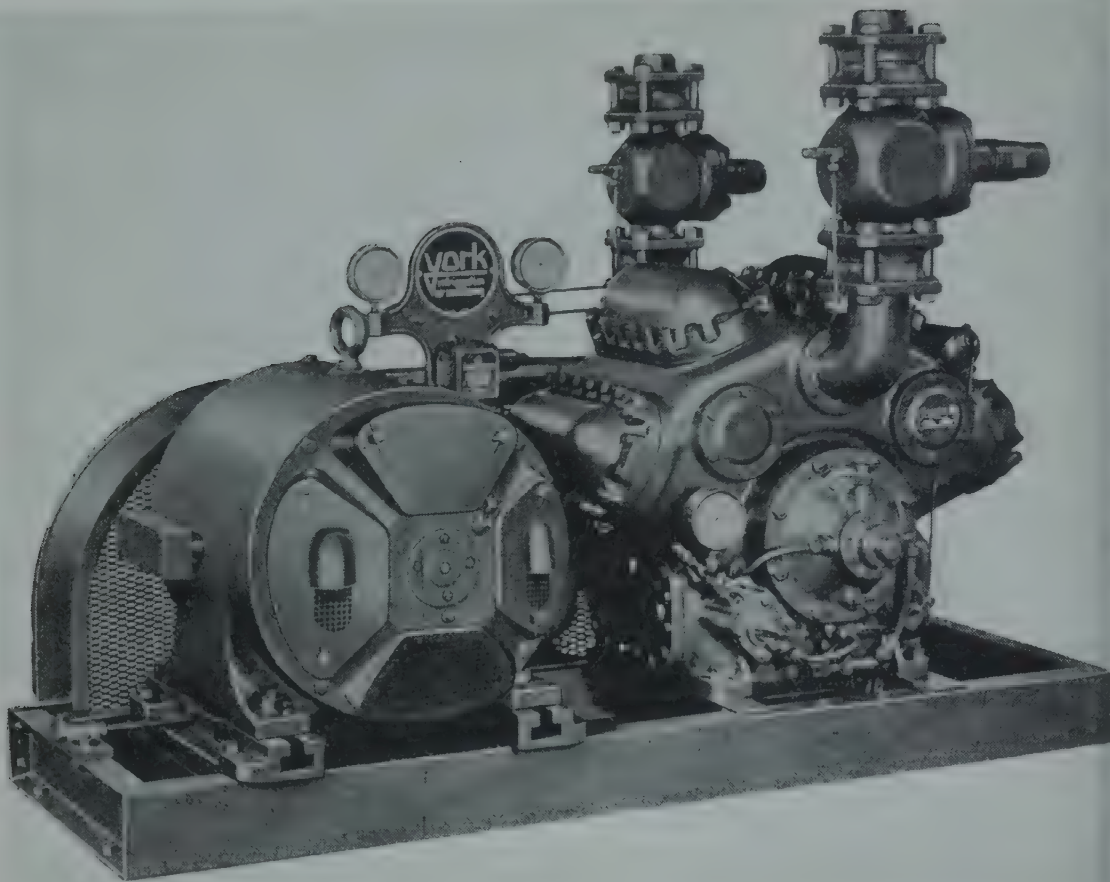


Fig. 9. York W. Type Belt Driven Compressor.

properties, toxicity excepted. Ammonia is widely used on fishing and sea food processing vessels and except for its associated wartime hazards, this refrigerant may well be used on board any vessel, if by the use of brine distribution and by proper design of compressor rooms, the ammonia can be confined in safe isolation. Unless otherwise indicated, this treatise will describe Freon systems.

Compressors

Modern ships are now outfitted with refrigerators having a design minimum temperature of minus 10 F. This range may be reached without excessive compression ratios by ammonia compressors in single stage operation or with F-12 units in compound compression or brine cascading.

The difficulties accompanying the leakage of air and air-borne moisture into a refrigerating system are well known, and these problems are minimized when the low side can be maintained at or above atmospheric pressure. Centrifugal compressors using F-11 and operating at pressures below atmosphere have little trouble from this source because of the effectiveness of shaft seals characteristic of rotative machinery and the continuously operating purging units auxiliary of this type of compressor. The use of brine circulation is mandatory for centrifugal systems using F-11. Certain successes can be pointed out for the operation of single stage reciprocating machinery in high compression ratios and suction pressures below atmosphere, but the traditional conservatism of the ship operator having given him good returns in all marine design, would call for positive pressure operation and low ratios. Conservative design in terms of rotative and piston speeds of reciprocating units are also looked upon with favor by the practical shipowner.

Reciprocating F-12 compressors cannot be operated in parallel because of the tendency of the oil to leave the crank case with the refrigerator flow and in returning to flood one unit and starve another. In consequence, each direct expansion evaporator system should be served by its own compressor. In multiple evaporator direct expansion plants, the large number of compressor units is undesirable, and the use of paralleling brine systems with fewer condensing units is recommended.

Capacity controls of compressors may be effected by speed variations or by automatic cylinder cut-outs, unloaders or bypasses. Intermittent operation or cycling should be reduced to a minimum by speed regulation or unit sizing to provide maximum uniformity in plant conditions.

Centrifugal compressors are essentially large tonnage units and the capacities are varied by speed controls, by-passing, throttling or metering of refrigerant, and the condenser pressure control by circulating water flow.

Reciprocating units are V-belt driven or direct connected to an electric motor, or in some cases to high speed steam engines. Centrifugal compressors may be driven by a step-up gear and motor or by steam turbine direct drive. The use of a steam turbine reduces electric generator demands and often fits nicely in the main steam plant heat balance.

Compressors of all types should be installed in a fore-and-aft centerline position to reduce the effect of gyroscopic bearing loads when the ship rolls. This position also favors lubrication of the unit.

Reserve compressor capacity and spare part lists are specified by the American Bureau of Shipping. This Agency recommends two condensing units, one of which running continuously should be capable of maintaining full cargo lading in tropic waters. The rules further state that when refrigerated spaces are of 15,000 cu ft total capacity or less, consideration would be given to the installation of a single condensing unit, there being carried adequate spare parts. An experienced ship operator would consider that numerical machine

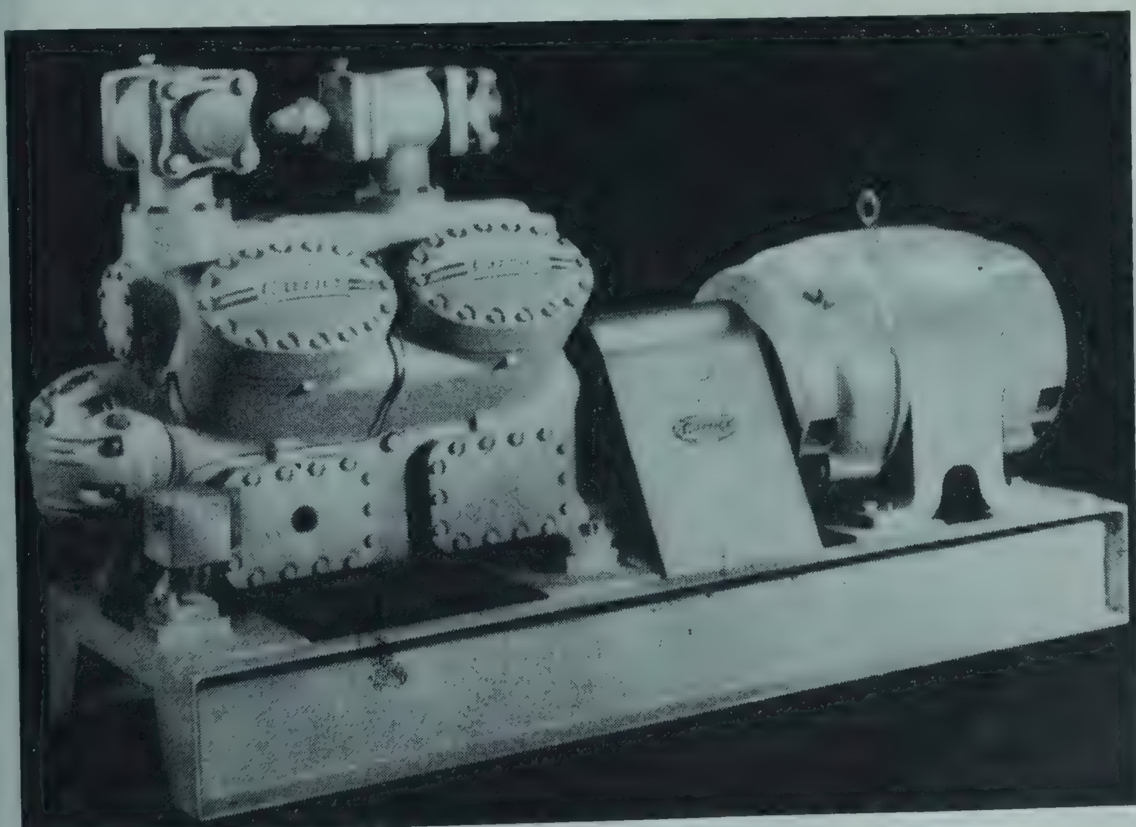


Fig. 10. Carrier Direct Connected Compressor.

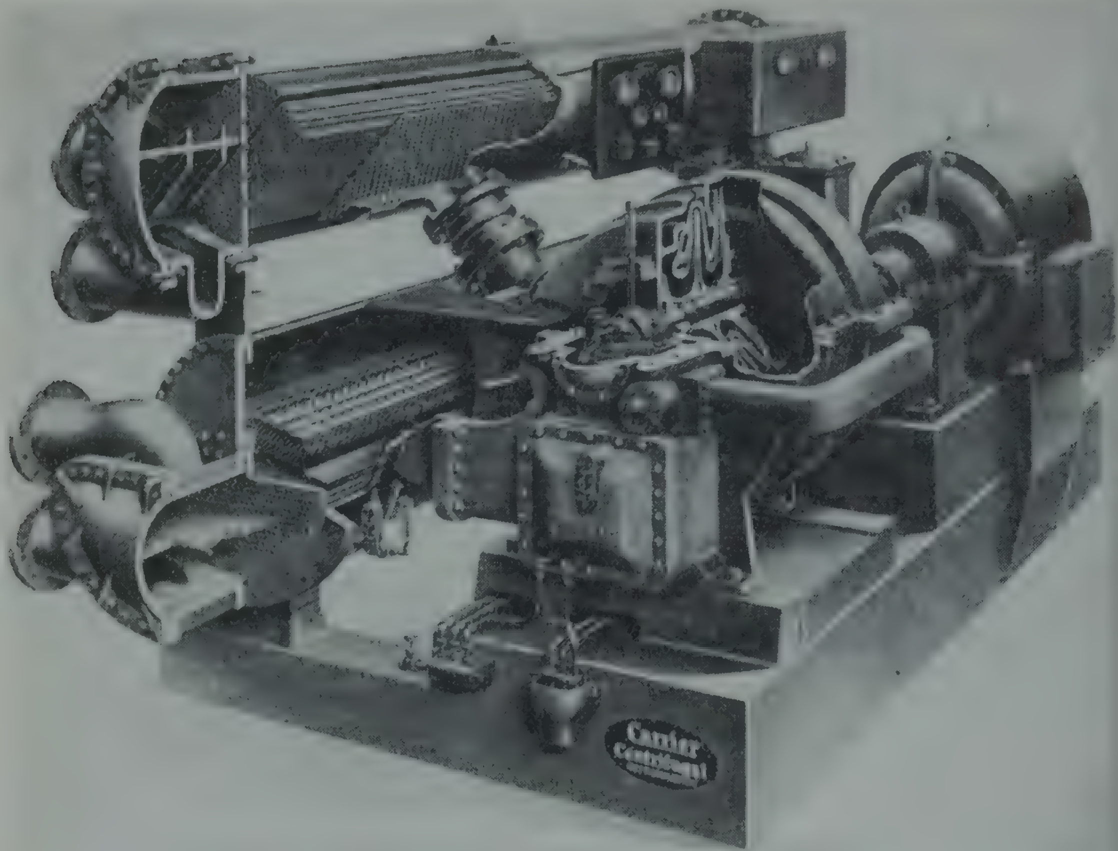


Fig. 11. Carrier Centrifugal Compressor—Broken Section.

reserves are as necessary as reserve in tonnage capacity and would no doubt exceed these minimums. The following table is recommended for all types and sizes of installations, giving full consideration to flexibility, reliability and plant efficiency. Tonnage capacity and reserves will be considered again in reference to load calculation.

Table 1. Operating and Reserve Capacities Condensing Units

No. of Units 100% Load	Additional or Reserve Units, %	Total No. of Units
1	100	2
2	50	3
3	33⅓	4
4	25	5
5 or more	20	6 or more

Condensers

Freon condensers are of the conventional shell and tube design, Freon refrigerants being non-corrosive to all commercial metals commonly used in refrigeration, a wide choice of materials is available. High heat transfer characteristics and resistance to corrosion-erosion by circulating sea water should be considered in the selection and design.

The refrigerant is usually between the tubes and shell of the condenser and the sea water circulates through the tubes in multiple pass arrangement. Steel or copper shells, cupro nickel or aluminum brass tubes and cupro nickel tube sheets are usual. Water boxes may be of cast iron or bronze, preferably the latter. The tendency to substitute high velocities of circulating water for cooling surface in heat exchange should be resisted, to provide long life. Water velocity in the tubes of 5 feet per sec is considered high and water box velocities above 2 feet per sec are conducive to turbulence and accelerated erosion of tubes.

Cooling surface requirements are subject to calculation for known maximum conditions. Navy standards call for a minimum of 14.2 sq ft per ton of refrigeration with compressor suction of +5 degrees. Higher temperature suction reduces required areas of cooling surface and lower temperature suction increases the minimum areas.

Condensers should be so installed that during the roll or pitch of the vessel or with a list, the condensed liquid refrigerant will properly drain to the receiver.

Receivers

Receivers may be of welded steel and should be arranged to insure submergence of the liquid outlet under all sea conditions. The receiver should have sufficient capacity to hold a complete charge of the system, plus 20% reserve volume. Means should be provided for the operators to observe the liquid level.

Brine Coolers

Brine coolers are subject to specifications similar to those of the condensers except that the materials must resist corrosive effects of the brine, steel tubes and tube sheets being usual. In conventional design the refrigerant circulates through the tubes to reduce the refrigerant charge to a minimum and provides maximum wetting of cooling surfaces. Large size coolers may have two or more independent tube groups, in parallel arrangement, each with its own expansion valve. Multiple parallel expansion results in improved flexibility, increased reliability and better control at partial loads.

Distribution of Refrigeration

Distribution of refrigeration may be provided by direct expansion systems or with brine as the secondary refrigerant.

With the refrigerated compartments located remotely from the machinery, direct expansion systems have many shortcomings. The extended return lines require considerable total pressure drop to produce velocities at low load that will return the oil to the machinery. The full load condition on the same line will add considerable duty to the machinery, and the resultant rarified vapor reduces the capacity of the compressor cylinders. When the evaporators or the return lines are lower than the compressor suction, oil traps are possible which may cause, under certain conditions, alternate starving and slugging of the compressors. The long low-side lines are generally concealed by insulation or are inaccessible for repair at sea or when the ship is loaded. If, through vibration, the flexing of the ship, or by damage, these lines develop leaks, serious consequences may follow. In addition, the extended systems require large charges of refrigerant with many more scattered points where moisture or air could find ingress to the system.

Because of its historic background, brine is often wrongly associated with obsolescence; yet the distribution of refrigeration by this means has many advantages over direct expansion systems. It permits the confinement of a fugitive refrigerant to the machinery room and the short lines result in small total pressure drops, efficient layout with fewer units, and in arrangements that facilitate the return of the oil to the compressors. The brine having a large sensible heat capacity, absorbs abrupt variations and eliminates the unwanted sensitivity of control that is characteristic of direct expansion, latent heat systems. While the brine-cooling refrigerant should be automatically controlled, best results in room conditions are obtained with manual control of return brine flow. Thermostatic operation of brine valves require temperature variations for actuation, while stable conditions can be established satisfactorily with constant rates of brine flow, the human element notwithstanding. As before stated it is not feasible to parallel Freon compressors aboard ship, but any combination of brine systems can be arranged to compound or divide refrigeration loads.

Space Cooling

To one not familiar with marine practice, the logical question arises as to why there has been so little research on distribution of refrigeration within cargoes aboard ship, after the manner of the conventional tests made in reefer cars or in the warehouse.

Rail cars have a degree of uniformity of

proportion in regular dimensioned enclosure and are loaded with a single type of commodity in an established manner. These tests are representative of a great majority of repetitive loadings—and have significance. Unlike warehouses, ships' refrigerators are tightly stowed without aisles or clearances and the method of stowage is even more influential of results than is the design of the refrigeration equipment. Marine refrigerators are, of necessity, of countless variations in size, dimension, proportion or configuration.

For homogeneous cargoes, such as citrus fruits, bananas or apples, tests in a ship's individual refrigerator would have significance, but with the usual heterogeneous cargo offered, the possible variations in stowage methods and the lack of uniformity of refrigerator physical characteristics, research in such matters has limited value. Practical considerations and critical observations of outturn results are the principal rule and guide to procedure, all of which adds up to an accumulation of experience by the operator.

Circulating air is the conveyor system which lifts the heat from the cargo or other sources and carries it to the refrigerating or heat-absorbing surfaces. Air, with its low specific weight and low specific heat, is not an efficient transporter of heat, and in consequence, relatively large volumes of air must be circulated. Restricted streams of air in high velocity have their equivalent in broad streams of low velocity. For effective heat removal a long air path will require higher velocity than the short path in lower velocity, with equal air stream temperature rise. High velocity streams will wipe air films of high humidity from the loading surfaces and replace them with air of lower humidity, thus accelerating dehydration of a vulnerable product.

Refrigerating air may be cooled by wall coils or dry type forced air cooling units. Ceiling coils are purposely omitted for the reason that cargo would be damaged by "sweating" or defrosting, and drip pans are impractical aboard ship. Wet type or brine spray units are not considered suitable for ships in a seaway.

Wall Coils

Wall coils have advantage in their short broad path of air circulation and the associated low velocities. They provide effective refrigeration within their limits, and for equal temperature split between refrigerant and air, they will minimize loss of moisture by the cargo.

Wall coils have a limitation in the horizontal distance into the cargo space to which they can provide effective refrigeration. With gravity circulation of air (which is not recommended), the wall coil could be expected to refrigerate at a horizontal limit of one wall height. With circulating fans

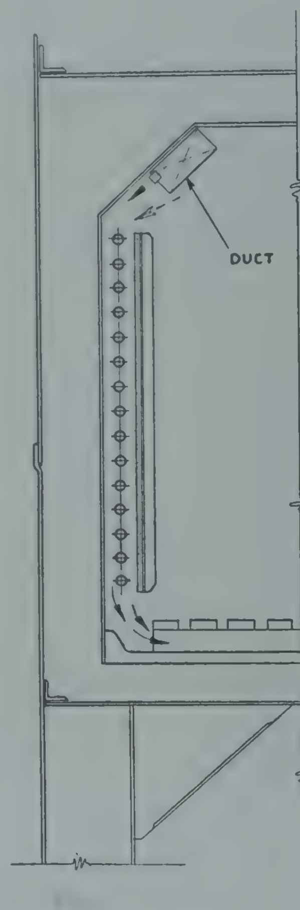


Fig. 12. Section Showing Wall Coil Baffle and Ducts.

the coils will refrigerate at a distance of $1\frac{1}{2}$ wall height. Above these limits, other means of refrigeration is applied.

Proper installation of wall coils include a solid baffle over the face of the coil forming an enclosing flue. The baffles should extend from near ceiling to near floor and may be lightly insulated. They should be fitted

with battens to prevent contact with cargo that might be subject to damage by low temperatures. Circulating fans should be installed at the ceiling and accessible from entrance doors. No suction duct is required but the fans should have ducts distributing the air to the coil walls. The ducts should discharge over the coil but not be enclosed by the baffle, as air jets from the duct outlets will induce air movement from the adjacent ceiling areas, and should the fans fail gravity circulation will maintain refrigeration of the room. Circulating fans not only increase the efficiency of the coils, but they effectively prevent stagnant air

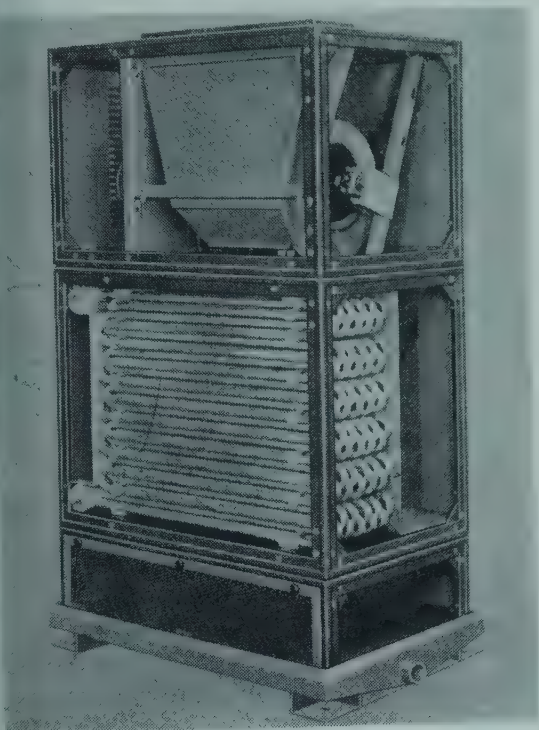


Fig. 13. York Cold Air Unit.

zones within the room and equalize the temperatures throughout the space.

For prime surface coils, $1\frac{1}{4}''$ pipe gives best economies. Direct expansion coils will not function properly as flooded systems aboard ship because of changes in liquid levels occasioned by loading trims or sea conditions. With direct expansion, care in design must provide that the last coil of a series does not become an oil trap. To avoid trapping the last coil should be fed at its top pass and return from the bottom pass. If the suction line rises, its size should be such as to assure an oil lift.

Coils should be designed for not more than 4 degrees refrigerant temperature rise per circuit, and coil lengths should be based upon that equivalent pressure drop. While authorities are not in full agreement on the U-value of bare pipe under these conditions, frosted coils with 10 degree MTD will probably not exceed 1.35 Btu per hr, per sq ft per deg MTD for Freon-12, and 1.6 for ammonia or brine. Multiple coil layouts should be arranged for well distributed refrigeration with any or all circuits in service. Additional basic data is found in other chapters of the Data Books.

Brine coils in any service should not be galvanized on the brine side and ammonia piping should be of black iron pipe. Freon-12 piping may be of any material common to refrigeration services.

Cold Air Systems

One of the better methods of refrigeration, particularly for chill cargo services, employs externally located coil bunkers and fan systems, which circulate chilled air through ducts and ported false bulkheads. Traditionally, the brine cooled prime surface hair-pin coils of pipe are used and the false bulkheads are at the ship's side, the air movement being athwartships. This system furnishes supply air to one side of the ship and the fans take suction from the opposing side of the compartment. Some installations are arranged to permit reversal of the direction of the air flow. Because of the uniformity of air distribution through the entire length and breadth of the compartment, refrigeration will effectively reach the entire volume if properly stowed and the ports are correctly adjusted. The usual distribution results in low air velocities and a relatively low moisture pick-up.

By calculating the refrigeration load and establishing the desired air temperature rise, the fan size can be readily calculated, and coil surfaces are determined after the manner of other air cooling devices. Several parallel coil circuits in series with the air stream will provide good control.

European builders often employ vertical air streams between floor and ceiling plenums, but this system has not been adopted by American operators.

Cooling Units—Diffusers

In compartments too large for effective refrigeration by wall coils, or by designer's choice, cold air units or diffusers are installed. They are composed essentially of three sections, the bottom as an air inlet, the middle section encasing the cooling coils and the top section housing the motor driven fans which are usually in multiple arrangement on a common shaft. Large units may be arranged horizontally in similar sequence. Diffusers are packaged units, easily and cheaply installed.

These units are fitted with distributing duct systems outlining the rooms, the outlets directing the air inward along the ceiling and downward along the bulkheads between the cargo battens.

The cooling coils are in some cases direct expansion small tube evaporators with fins spaced fractions of an inch, each vertically arranged tube pass being fed liquid from the distributing head of a thermo-expansion valve. The evaporator outlet consists of a connecting manifold at the base of the coils. Other types employ prime surface tubes or coils cooled by direct expansion or by brine.

The manufacturers of the units are usually willing to specify cooling surface areas based upon the calculated load of the individual installation. The ratios of cooling surface areas to refrigerator volumes are often referred to, but are not a scientific basis in design. The ratios, however, provide ready comparisons of competitive designs or proposals.

Most marine refrigerators operate at temperatures that require the cooling surfaces to be below 32 F and these surfaces rapidly accumulate frost. The relatively small cooling surface areas of a cold air unit become thickly coated and the restricted air flow becomes so impeded that defrosting is necessary. Prime surface coils will, while losing in heat absorbing capacity, present increasing heat absorbing surface by the coat of frost, providing a small degree of compensation. Generally speaking, prime surface coils require less frequent defrosting than extended surfaces of equal rated capacity.

Very large fins widely spaced will function similarly to prime surfaces, but closely spaced fins may become completely blocked without frequent and thorough defrosting. The consequently reduced area of the air stream and the masking of the heat absorbing face by frost, reduces the refrigeration capacity of the unit. The effect may be avoided to a degree by a small temperature split between refrigerant and the air, and a compensatingly generous cooling surface ratio. The problem becomes most severe during initial cooling periods.

Cooling units or diffusers are installed behind guards or fenders against which the cargo may be piled and behind which necessary access is provided for the maintenance of motors, fans and control valves. The cargo space lost to these units and their associated ducts increase proportionately as the room becomes of smaller volume and there is an economic balance at which the wall coil arrangement becomes the more desirable.

Despite their popular use on American vessels and creditable performance, cold air units have some faults in their usual application. The ducts may distribute the air evenly about the periphery of the entire room but the return air is lead to and through a relatively small diffuser inlet. The resulting tendency is to provide negligible air velocity and heat pick-up in the end of the room most remote from the return inlet and as the stream successively picks up the distributed air, the velocity increases in its converging path, until a maximum is reached at the cooling unit. This is not conducive to uniformity in room temperature and humidity conditions. High air velocity over the surfaces of products subject to damage through moisture loss is detrimental to such cargo. Leafy vegetables and similar perishables stowed close to distributing duct outlets, and those stacked near to the unit inlet where velocities are high, may be damaged by dehydration. This problem is minimized by good stowage methods, multiple unit arrangement in large rooms and by operating the fans at their lowest practical speed. Fans should have output adjustment in steps to half-rated speed and the motors should be of watertight design to prevent damage to windings or armature by internal motor sweating. The rate of air

change will respond to calculations as for the cold air systems described above.

Defrosting Systems

All cooling surfaces should have means for the melting of accumulated frost. Direct expansion systems, if not too remote from the compressors, may be defrosted by hot gas, or alternately with warm water spray. Hot gas defrosting is accomplished by reversing the flow of compressor discharge, the evaporator becoming a condenser where sensible and latent heats are absorbed by the frost. The liquid so produced must be accumulated and expanded in another evaporator, or with care in control it can be expanded in the condenser, gaining the heat for evaporation from the sea water. Hot gas defrosting is not without complications and most plants employ heated fresh or sea water for the purpose. When using heated water, its temperature should not exceed 90 degrees to avoid high refrigerant pressures in the evaporator.

Brine cooled surfaces may be defrosted by by-passing heated brine through the coils. The frost is first melted at the coil surface and rapidly displaces the frost as water and ice. A steam heated thermostatically controlled brine heater may be installed in central location for the purpose.

Replacement Air

In some long voyage chill services, such as for bananas, citrus fruits, apples, etc., replacement air is necessary to remove excessive quantities of carbon dioxide and other gases. For uniformity of conditions within the room, the air should be of continuous addition rather than intermittent. The new air should first pass through the cooling unit before distribution, if constancy of temperature and humidity are to be effected.

Citrus fruits should have replacement air at the rate of 2% to 3% per minute based upon the gross volume of the refrigerator and bananas may require as much as % gross replacement.

When replacement ventilation is provided, accessible, efficient and well-insulated dampers should be fitted for cutting off this air supply when frozen food is carried.

Plant Lay-Out and Piping

The first rule in plant lay-out aboard ship is that it should have an optimum of simplicity without the sacrifice of reliability. The second rule is that the machinery plant should be closely associated with the main power plant to provide short piping and power connections and to facilitate close supervision by engine watch officers. The not unusual exchange of engineers and the more frequent replacement of refrigeration crew members demands that strangers to the installation should be able on short notice to trace out the well-labeled systems and place the plant in operation or maintain it without undue hazards to the machinery or the cargo through error in manipulation or adjustment. A third rule in lay-out demands that even at the expense of valuable revenue space, an uncrowded machinery room be provided which will give ample space for operations, maintenance and repair of apparatus or ship's structure and that proper clearances be allowed for the insulation of low temperature parts.

All machinery should have sturdy foundations and all parts secured against vibrations set up by themselves or the main propulsion plant. High speed machinery should be mounted on fore-and-aft centerlines and all gravity feeds, drains or tanks should be designed or installed with full considerations of the effect of trim, roll or pitch of the vessel in a seaway.

With Freon-12 condensing units each individual system must consist of compressor, condenser, receiver and evaporator and they must work independently from other systems in the primary refrigerant side. The number of units for a plant should be as indicated in Table 1, and the entire plant should be cross-connected in a manner that the standby units may take the load from any system normally assigned to a specific use.

It is apparent that multiple compartmented refrigerator arrangements operating with direct expansion, can at best become a complicated central plant layout, particularly with hot gas defrosting. Remotely located evaporators result in decentralized control with apparatus scattered over the ship. A typical lay-out of

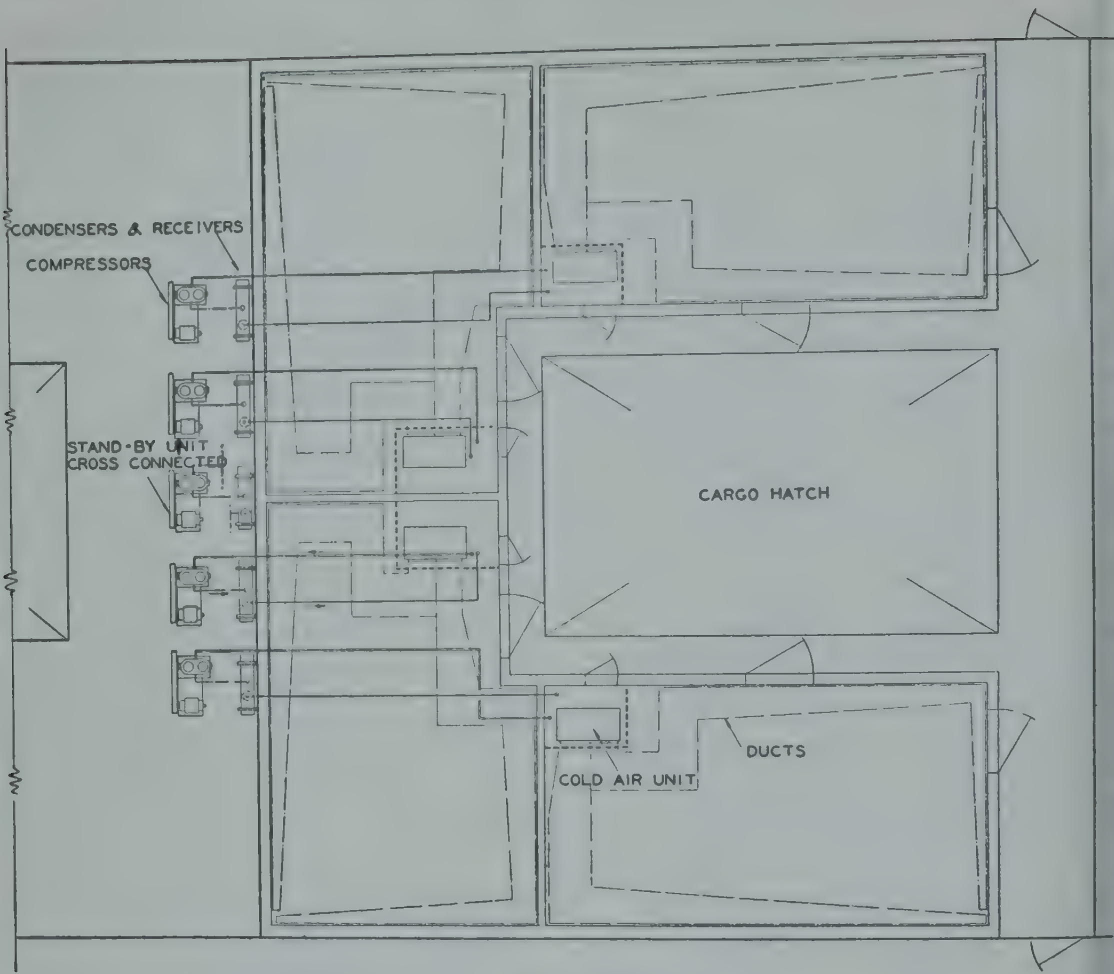


Fig. 14. Direct Expansion Plant.

essential machinery and piping of a small plant is shown in Fig. 14.

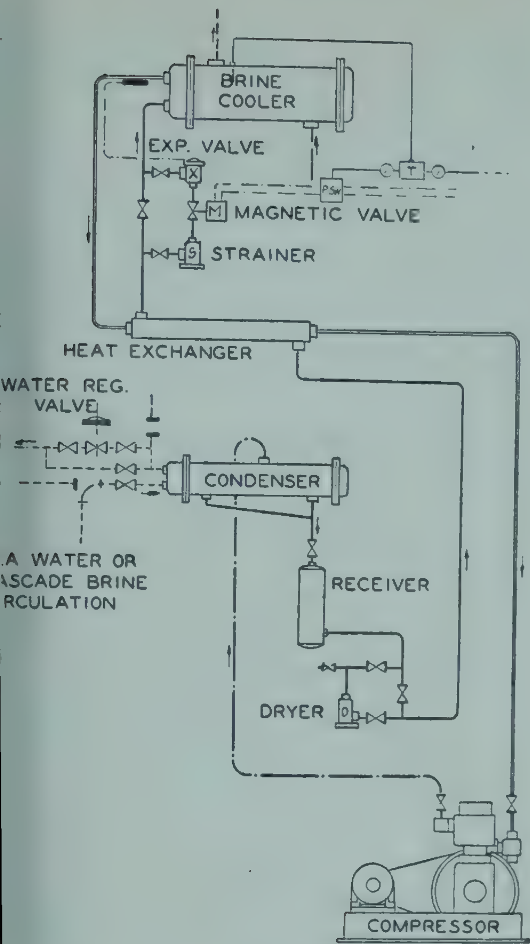
Freon return piping may be designed on the basis of a 2 F total temperature drop between the evaporator and the compressor. The aforementioned oil trapping should be avoided and a heat exchanger for cooling the liquid should be fitted, preferably close to the evaporators. Minimum vapor velocities of 700 to 800 feet per minute are recommended for oil return flow.

Liquor lines should be arranged to prevent line flashing from excessive pressure drop in the static head of risers or from high temperature and the heat exchanger location may be affected by this consideration. Liquor lines should be fitted with efficient driers and strainers. Other conventional fittings and apparatus are fully described in manufacturers' literature and require no further treatment in this section.

Plants using brine for distribution of re frigeration require a condensing unit fo each evaporator, after the manner c direct expansion plants, but any arrange ment of cross connection of brine system may be effected with impunity.

Most marine plants operate over a wid range of refrigerator temperature fror sub-zero to ambient, with any or all com partments interchangeable. This arrange ment suggests a two-temperature brin plant in which the high temperature brin may refrigerate fresh products with mini mum dessication effect, and a low tem perature brine for refrigerating frozen car goes.

A two temperature brine plant suggest two circulating piping systems served b two pumps on the line and a standb pump available for either system. Th lay-out is best provided by two circulatin



(a)

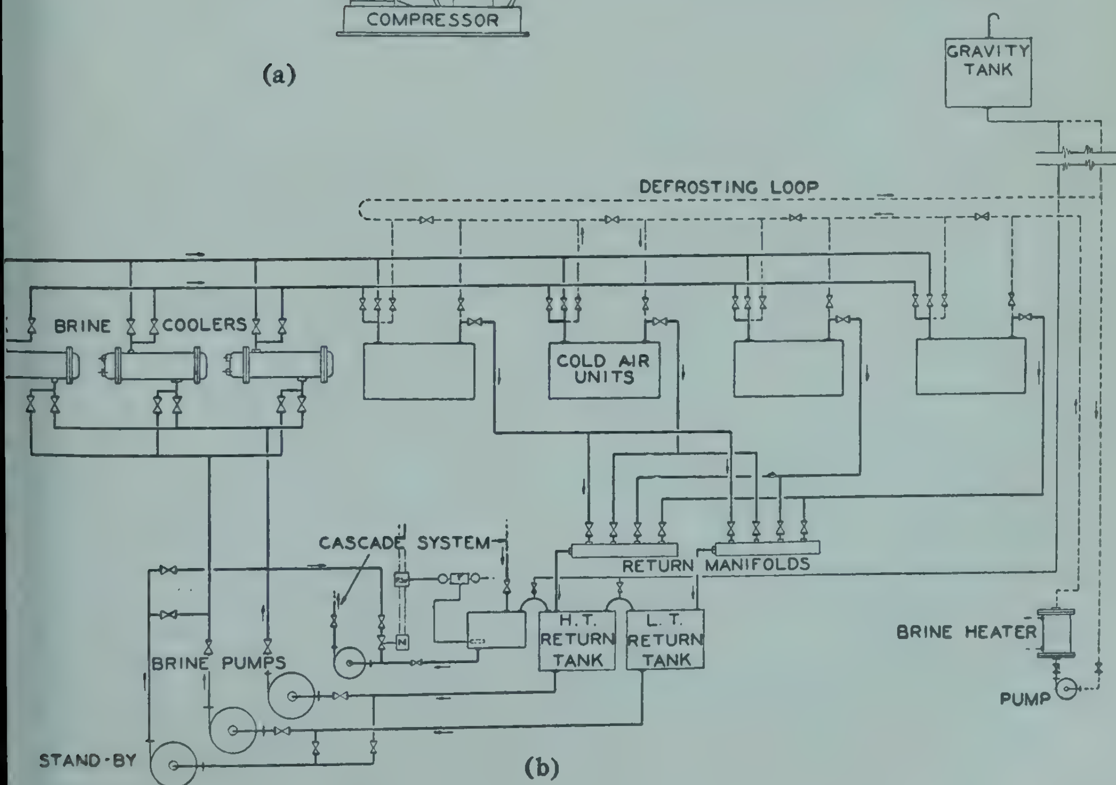
loops from which, by setting valves at the refrigerators, one can selectively utilize the desired brine.

Brine returns from each cooling unit should run individually to the central plant return-valve twin manifold where room temperatures may be remotely controlled by brine flow. By controlling return flow the systems are under pumping pressure to the return valve and airbinding will be at a minimum.

The returning brine is diverted to its respective collector tank from which the brine pump takes its suction. Two types of systems are in use, one in which the return brine streams are in view of the operator, providing the so-called open system, and the closed system in which a static head is maintained on the enclosed return tank and system by a vented overhead gravity tank. These same brine systems may be used with plants using other than Freon-12 as a refrigerant.

With the use of brine for distribution there results an additional temperature differential between the primary evaporat-

Figs. 15a and b. Freon-12 and Brine.



(b)

ing refrigerant and the compartment air temperature. With a room temperature of minus 10 F and Freon-12 as a refrigerant, compounded effect is desirable by the cascading of the refrigerant plant. In this operation the high temperature brine is circulated through the condenser in lieu of sea water, thus reducing head pressure and compression ratios over that of single stage compression.

To facilitate staging by this method a cascading brine pump is suggested which will recirculate its own allotment of brine at a predetermined temperature thermostatically maintained by a pilot feed valve which will control the addition of low temperature brine.

For defrosting with hot brine an independent small pipe loop is suggested, it having its own pump and heater. In this operation the cold brine valves are closed at the refrigerator, and the cooling coils are placed in series with the pump and heater. By this system the brine content of the coil only is displaced which foregoes the heating of an entire pipe line. Should the volume of the whole circuit be returned to the circulating system, it would for an interval, affect the equilibrium of the entire plant.

Thermometers

The principle indicator of the functioning of a refrigerator plant is the thermometer. Those instruments associated with the central machinery plant reflect thermal efficiencies of the plant, and their purposes and location are well defined. They need no further description here.

The end results of the applied refrigeration, namely space temperature levels and control, are indicated by the room thermometers. The definition of room temperature is fixed to the location of the instrument's sensitive bulb within that space. Refrigeration is affected only by the temperature rise of the refrigerating air stream and it must follow that all parts of the room enclosure are not the same temperature reading. The proper location of the sensitive bulb in relation to the air stream is subject to study and perhaps compromise.

In rooms operating with considerable margin below or above the freezing temperature of the product, the bulb can be located with considerable tolerance, but in rooms operating in a close range above the commodity's freezing temperature, care must be exercised that damage may not be done in cold zones while the thermometer is indicating a safe reading. In most ships the spaces are convertible to any temperature and the positioning of the bulb is critical. There will be cases when the operator should know this and apply refrigeration accordingly.

Ideally, there should be several thermometers planted throughout the stowage. Practical requirements, however, demand that the bulb be secured to the structure, in a location believed to be representative of average of the room. The bulb should be so installed that there will be no false readings due to being in direct contact with warmside surfaces, refrigerating equipment or due to proximity of wall coils.

Wall coil rooms will usually have the bulbs located at the geometric center of the ceiling while rooms fitted with cold air units will have the bulbs located at the inlet opening. The return air in a room properly stowed, should be the warmest point in the air stream, and with reservation, may be considered the room temperature.

Indicating thermometers inserted in walls through the insulation are not satisfactorily accurate or representative. Indicating dial thermometers should serve each room with the dial installed externally and near the access doors. All bulbs used for comparative readings should be installed adjacent each to the other. Switch operated, electric resistance indicating thermometers should be installed with the di[al] located at the log desk.

Recording thermometers are essenti[al] to proper operation and management [of] cargo refrigerators. Mercury actuated instruments, will, due to system limitation[s], have the instrument near the refrigerat[or]. Electric resistance recording instrumen[ts] are best located in the machinery roo[m] where they are under constant observ[a]tion.

Disc charts showing seven days oper[a]tion are satisfactory for mercury actuat[ed]

nstruments. The cases of these units should be fitted with lock and key to prevent tampering by unauthorized persons. The roll type charts of the electric resistance recording thermometer is most satisfactory. The ideal for roll type, marine recording charts would permit readings of one-half degree, have a travel of one foot in twenty-four hours, and with unlabelled quarter hour and one hour rulings. The instrument should automatically mark clock readings and be capable of hand resetting with the daily changes in longitude reading of the vessel's position.

All charts should be accessible for notations explaining any irregularities in temperature control, for the information of the shore management that supervises operations and for those who settle complaints or claims. Each ship should be supplied with a rubber stamp as illustrated below, applied to each chart, the data entered, before depositing with the appropriate shoreside supervising officers.

. S. __________ Voy. ________ Bound________

Date__________________________________

Rm. No.	Spec'd. Temp	Cargo	Del. Cond.

Specification of Conditions

Most refrigeration plants are installed by shipbuilding or repair yards on a contract basis. Usually the erection of the insulation is sub-contracted and the machinery components separately handled through purchases by the yard or the ship's owners.

Without carefully stated operating conditions the responsibility for successful performance is lost in division and without them wide variations and alternatives may be expected in the proposals from the machinery vendors.

The specifications should be composed by, or with the help of, experienced persons intimately familiar with the practical operations of such a plant and the particular trade. They should represent the extreme demands upon the plant in terms of lading, ambient temperatures and pull-down periods.

In the all-purpose installation each compartment should be designed for the refrigeration of warm fresh products from the field or orchard, and for the over-all condition, a percentage division of chill and freezer cargo with simultaneous and total loading should be stated.

Typical conditions will include the following information:

(a)	Arrangement and net cubic capacities of the refrigerated compartments	
(b)	Thicknesses and kinds of insulation	
(c)	Ambient temperatures	
	Weather Surfaces	100 F
	Adjacent Machinery Spaces	100 F
	Other Adjacent Spaces	85 F
	Sea Temperatures	85 F
(d)	Over-all stowage factor, cu ft per short ton	70
(e)	Percentage total loading as chill	75%
	Percentage total loading as freezer	25%
(f)	Receiving temperature, chill cargo	80 F
	Receiving temperature, frozen cargo	25 F
(g)	Carrying temperature, chill cargo	35 F
	Carrying temperature, frozen cargo	Minus 10 F
(h)	Equivalent period of cargo pull-down	72 Hours
(j)	Replacement Air, 85 DB-75 WB.	3%

The owner should describe the kind of refrigeration system to be installed and specify the number of compressors and other auxiliary parts or apparatus, together with sources of emergency pumping and water facilities.

All equipment and installations must be specified as complying with the rules and regulations of the Classification Societies (American Bureau of Shipping, and/or Lloyd's Register, etc.), The U. S. Coast Guard, the U. S. Public Health Service and

the ASRE Standard 26, "Recommended Practice for Installations on Shipboard."

Unless the specification writer wishes to assume full responsibility for the functioning of the plant and all its parts, he must avoid specifying machinery characteristics other than limits of types, speeds, velocities, etc. He should, however, exact from the vendors fullest details, description and capacities of the equipment they propose to furnish to permit comparative analysis of the several proposals.

Completion tests should be required to determine workmanship and functional performance. The traditional temperature tests made upon the empty refrigerators are meaningless because of the inability to set up standard ambient or weather conditions, and to determine influences of heat capacities of insulation masses, equipment or residual refrigerants, as well as that of volume-to-exposure area relationships.

Calculation of Refrigeration Loads

Because of the extreme and variable conditions under which a sea-going cold storage plant must operate, there is little justification in applying the design minutiae that is common in many other applications. The factors of heat resistance of air films, the calculations of heat gain from beam or frame flanges under reduced insulation thicknesses or the consideration of the conductivity of steel enclosures or refrigerator linings are not of comparative

A suggested form and method for calculation of refrigeration loads follows:

CALCULATION REFRIGERATION LOAD

CHILL CARGO BASIS

SS AMERICAN SPACE NO. 1 VOL NET 5780 CuFt = 165,540 LB
RECEIVING TEMP 85 F CARRYING TEMP 35 F
SPECIFIC HEAT .9 RESPIRATORY HEAT RATE 100 BTU/HR/TON
CARGO PULL DOWN PERIOD, 72 HOURS EQUIVALENT
HEAT EQUIVALENT FANS 3000 BTU/HP
REPLACEMENT AIR 2% OF VOLUME PER MINUTE

LEAKAGE HEAT

Surface	Area	Insul	Thick	K	U	(T_1-T_2)
Deck	800	Corkboard	6″	.28	.047	85–35
Deck-head	800	Corkboard	8″	.28	.035	100–35
Ship's Side	200	Corkboard	10″	.28	.028	100–35
Bulkhead, Fwd / Bulkhead, Aft	265	Corkboard	6″	.28	.047	85–35
Bulkhead, Inb'd	475	Corkboard	5″	.28	.056	85–35

Surface	Area ×	U ×	(T_1-T_2) =	BTU/HR
Deck	800	.047	50	1880
Deck-head	800	.035	65	1820
Ship's Side	200	.028	65	364
Bulkhead, Fwd / Bulkhead, Aft	265	.047	50	623
Bulkhead, Inb'd	475	.056	50	1330
		TOTAL		6017
		PLUS 10% OTHER GAINS		603
		TOTAL		6620 BTU/HR
		EQUIV. TONS		.55

PRODUCT LOAD

SENSIBLE HEAT = $\frac{165{,}540 \text{ LB} \times .9 \times (85-35)}{72 \text{ HR}}$ = 103,462 BTU/HR

RESPIRATORY HEAT = $\frac{165{,}540 \text{ LB}}{2000} \times 100$ BTU/T = 8,277 BTU/HR

TOTAL 111,739 BTU/HR

EQUIV. TONS REF. 9.31

REPLACEMENT AIR LOAD

REPL'T 2 %/MIN = 115 CFM
OUTSIDE DB 85 F OUTSIDE WB 75 F TH 37.65 BTU/LB
INSIDE DB 35 F INSIDE WB 33 F TH 12.15 BTU/LB
SPECIFIC VOLUME 12.5 CuFt/LB TH EXTRACTED 25.50 BTU/LB

HEAT = $\frac{115 \text{ CRM} \times 60 \text{ MIN} \times 25.5 \text{ BTU}}{12.5 \text{ CuFt/LB}}$ = 14,073 BTU/HR

EQUIV. TONS REF. 1.17

TOTAL LOAD

LEAKAGE HEAT	6,620 BTU/HR
PRODUCT LOAD	111,739 BTU/HR
FAN LOAD 3 HP×3000 BTU	9,000 BTU/HR
REPLACEMENT AIR	14,073 BTU/HR
TOTAL	141,432 BTU/HR
EQUIV. TONS REF.	11.79

RECAPITULATION

Space	CuFt net	Short tons @ 70 CuFt/T	Tons Refr.
Room No. 1 Etc. Etc.	5,780	82.77	11.79
TOTALS	CuFt	S.T.	TONS

influence. On the other hand, margins in design should cover deficiencies associated with advancing age or for some exceptional load demand upon the plant. Heat gain through open doors is not of consideration in cargo refrigeration, because of infrequency and the total flooding of outside air during loading and discharge, all of which is included in the pull-down factor. The calculations, however, are worthy of more accuracy than that which comes from the traditional cubic-feet-per-ton ratio or other rule-of-thumb procedure.

Refrigeration loads for freezer cargo may be calculated in similar manner using the same stowage factor, a specific heat of .40 and an equivalent pull-down period of 72 hours. Respiration heat and replacement air loads will not be present.

Should a resultant total load of, say, 100 tons be indicated for a Freon-12 and brine plant, a satisfactory lay-out would provide four condensing units capable of maintaining the full load on continuous duty with a fifth unit as a standby.

If a Freon-12 direct expansion plant

were chosen, each room may be served by its own condensing unit, all preferably of common size. Spare units in cross connection are recommended as in Table 1.

A centrifugal compressor plant would be composed of two machines, each capable of maintaining the full load. If associated with a two-temperature system, three units, one a standby could be installed, or alternatively the brine system with two units could serve a high temperature brine recirculating system fitted with an automatic pilot valve feed from the low temperature system.

Summary

There are countless numbers of possible arrangements of marine refrigeration plants, each one influenced by the size and type of ship, by the trade, and by the convictions of the owner, the design engineer and the builder. The old procedures have given way to more scientific approach, but the opinions of the practical experienced operator should be given fullest consideration.

The examples and considerations outlined in this chapter are but typical and not offered as rigid limitations of good design. The marine application of refrigeration has, through trial and errors aplenty, seen extended development in the last decade and one can anticipate further improvements as new experiences are gained. The good of the old practices should be retained and proven betterments accepted.

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If you searched this chapter for something which was not found in it, please let the editors know.

SECTION III

REFRIGERATION IN FOOD MANUFACTURE

Dr. Bernard E. Proctor, Associate Editor. Born 5/5/01 in Malden, Mass. Educated at Massachusetts Inst. of Technology, Cambridge, Mass., PhD, 1927. Formerly, Instructor, 1927–30; Assistant Professor, 1930–36; Associate Professor, Food Technology, 1936–44; Professor, 1944 to date. Co-Author of "Food Technology," McGraw-Hill, 1937; Contributor to J. Am. Chem. Soc.; *J. Bacteriol.; Food Research; Refrig. Eng.; Food Technology; Nucleonics; Food Industries;* Associate Editor, *Food Technology,* 1947–49; Section III, 1946 Applications Volume, ASRE Data Books.

Chairman, Food and Nutrition Section, Amer. Pub. Health Assn., 1938; Biology Committee, ASRE, 1938–39; Director, Subsistence and Packaging Research, Office Quartermaster General, U. S. Army, 1943–44; Chairman, Northeast Section, Inst. of Food Tech., 1947; Coordinating Committee, 7th Annual Conference, Inst. of Food Tech., Boston, Mass., 1947; Vice-President, Inst. of Food Tech., 1948–49; Program Chairman, Division of Agricultural and Food Chemistry, Amer. Chem. Soc., 1950; Chairman, Division of Agricultural and Food Chemistry, Amer. Chem. Soc., 1950–51; Herman Frasch Foundation Awards Committee, 1947–51; Subcommittee on Special Rations, Committee on Foods, National Research Council, Advisory Board on Quartermaster Research and Development, 1950.

Member, Amer. Soc. of Refrig. Engrs.; Inst. of Food Technologists; Amer. Public Health Assn.; Amer. Chem. Soc.; Soc. Amer. Bacteriol.; A.A.A.S.

At present, Director, Samuel Cate Prescott Laboratories of Food Technology, M.I.T., Cambridge, Mass.

Chapter — Page

24. MEAT PACKING

REFRIGERATION is an integral part of packing-house operations since it is essential for the proper preservation and conditioning of the meat products. The operation, arrangements and types of facilities vary in different concerns and plants. It is not attempted in this chapter to discuss these variations, but to indicate generally satisfactory principles, facilities and operations.

I. CARCASS CHILLING AND HOLDING COOLERS

It is of the utmost importance that freshly slaughtered and dressed carcasses be placed in chilling coolers immediately in order to retard bacterial action. Carcass chill coolers must frequently serve the dual purpose of chilling and holding. There are specific requirements for chilling and conditioning of each of the species handled.

Hog Chilling Methods

The internal temperature of the hog carcasses entering the chill coolers from the killing floor usually varies from approximately 100 to 106 F. The specific heat is approximately .51 to .57. The dressed weight of hogs will vary from about 90 to 450 lb, the average being around 180 lb. There is a definite commercial advantage in cutting hogs the day after they are killed. This is now the usual practice, which limits chilling time to approximately 18 to 24 hr, depending upon the slaughtering and cutting schedules of the particular plant involved. There is less cooler shrink in hogs chilled for cutting the day after killing than if chilled for cutting the second day. Quick chilling is desirable during the first 12 hr, and particularly the first 6 hr, to inhibit bacterial action as a precaution against deterioration.

Chilling schedules vary. Typical time-temperature chilling curves for various sizes of hogs are shown in **Fig. 1.** It is desirable to provide sufficient refrigerating capacity so that the air temperatures during the peak load will not exceed 38 F. For optimum control, meat temperatures should be taken on representative carcasses in the centers of the hams and shoulders simultaneously at regular intervals—e.g., every 3 hr and just prior to cutting. The optimum spacing of the hogs on the rails in the chill coolers depends upon the efficiency of the cooler and the size of the hogs, though in no case should they be allowed to touch. Satisfactory spacing for hogs averaging 180 lb dressed weight is 14 in. center to center. Rail spacing varies, depending on the size of the hogs and also on the construction of the cooler, the range being from approximately 26 to 30 in. Rail heights vary in different plants from about 7 ft 6 in. to 11 ft 2½ in. The Meat Inspection Division of the Department of Agriculture requires, however, that the rail height in new plants engaged in interstate commerce be at least 9′0″.

It is obvious that the rate and amount of refrigeration and air circulation required depend mainly on the weight of the hogs, the spacing, the chilling schedules and the rate of cooler loading, i.e. slaughtering rate. It is not unusual for several, or possibly all, sizes of hogs to be placed in the same cooler; so for optimum chilling the

J. P. McShane, Author Chapter 24. Educated at Texas University, BS, 1927. Formerly, Engineer, St. Louis Dressed Beef Plant (subsidiary of Swift and Company), St. Louis, Mo., 1927–28; Asst. Chief Engineer, 1928–31; Engineer, Test and Experimental Work, Supervising Engineers Office, Swift and Co., Chicago, Ill., 1931–32; Chief Engineer, Neuhoff Packing Co. (subsidiary of Swift and Co.), Nashville, Tenn., 1932–37; Engineer, Supervising Engineers Office, Swift and Co., Chicago, 1932–49. Asst. Supervising Engr., 1949–50. Member, Amer. Soc. of Refrig. Engrs.; Chairman, ASRE Chicago Section, 1947–48; Chairman, Tech. Comm. A-3 on Meat Packing Plant Refrign., 1947–48; Chairman, ASRE Sections Committee, 1949; Member, Comm. on Rating and Testing Industrial Refrig. Equip., 1946 to present; ASRE Director (Chicago Section) 1948–50.

Co-author, Appln. Data Sec. 45 on Refrigeration Carcass Coolers; Author, Chapter 22, 1946 Applications Volume, ASRE Data Books.

At present, Supervising Engineer, Swift and Co., Chicago, Ill.

largest hogs should be placed so as to come in contact with the coldest air, if the refrigerating system permits, and also be allowed to remain in the cooler the longest time. Adjusting the spacing of the hogs according to size assists in obtaining correct temperatures.

For hogs to be in proper condition for cutting, not only must the internal meat temperatures be as specified, but also the carcasses must be firm, without any freezing of the ham or shoulder shanks or the bellies; be dry on the surface; and have a bright, fresh meat color. Freezing causes difficult and wasteful cutting and frost is detrimental in pork going to cure. Frozen surface moisture will thaw during cutting and result in excessive moisture on freshly packed pork; then, when this pork is held over for shipment in below-freezing temperatures, the surface moisture will freeze again, and upon final thawing the pork is likely to be discolored.

In order to chill the carcasses in the required time, condition them properly for cutting, and keep shrinkage to a minimum, it is essential to achieve proper relationship of air temperature (as indicated in Fig. 1), air circulation with good distribution, and humidity. During the early stages of chilling, the humidity is very high—95 percent or higher—due to the vapor from the hot carcasses; consequently rapid air circulation and a high rate of refrigeration are needed to remove the vapor and prevent condensation, as well as to effect the desired rate of chilling. Rapid air circulation also assists in obtaining uniform temperatures and is not detrimental during chilling from the standpoint of shrinkage because it quickly reduces temperature and vapor pressure at the surface of the carcass. Air circulation roughly equivalent to 75 to 100 air changes per hour in the cooler will give good results for the chilling schedules indicated in Fig. 1.

As the chilling progresses, the refrigeration rate is reduced as required to adhere to the chilling schedules and to condition the hogs for cutting. The humidity should be maintained at approximately 85 to 90 percent to prevent excessive shrinkage. Even though the desired internal temperatures are reached before it is time to cut the hogs, some air circulation must be maintained to prevent the hogs' becoming damp and "clammy" with resultant loss in keeping quality, and to prevent loss of bloom, i.e. color.

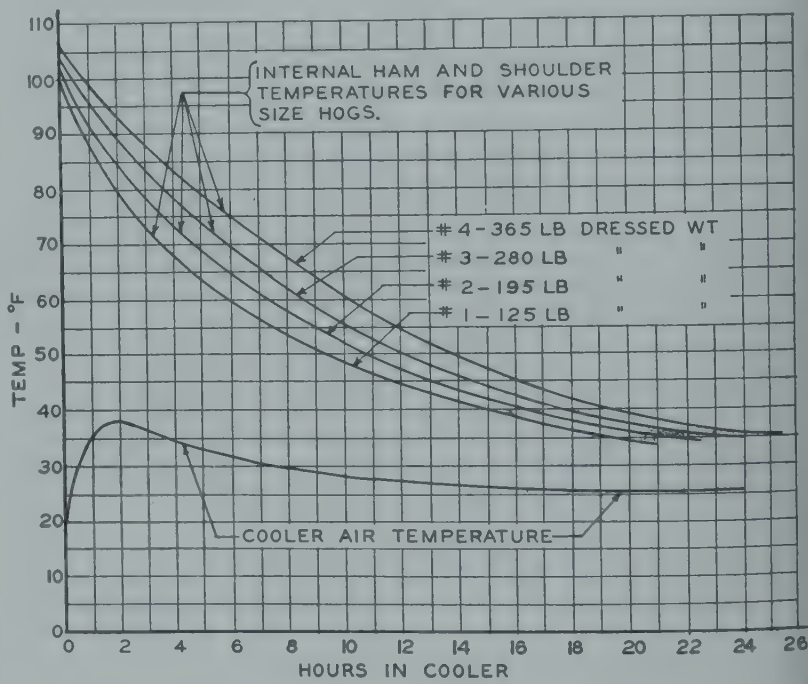

Fig. 1. Typical Time-Temperature Chilling Curves for Hogs.

There are many systems used for chilling hogs, three of which are outlined below.

1. **The overhead deck with brine sprays** is probably the most commonly used system at present, as in **Fig. 2.** Refrigeration and most of the air circulation are both furnished by the brine sprays. From the standpoint of air circulation it is advisable to limit the cooler width to approximately 50 ft, and, while many coolers of this type

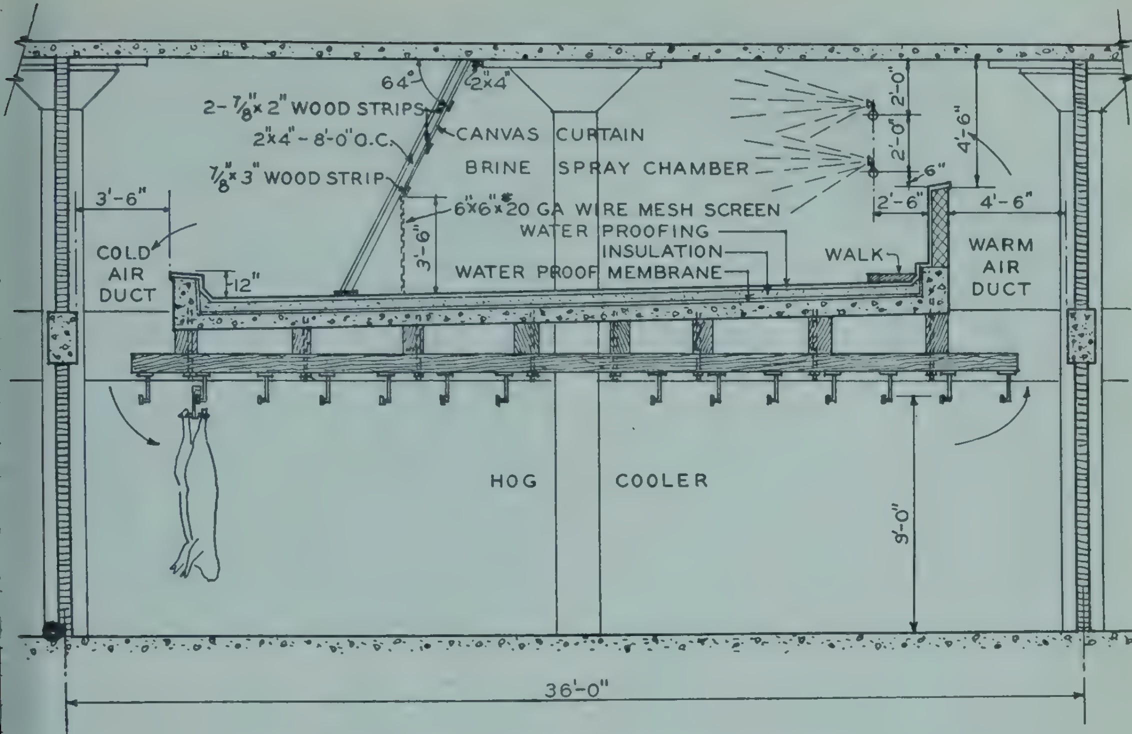

Fig. 2. Hog Cooler—Overhead Deck with Brine Sprays.

are 16 ft wide, it is desirable to have the cooler 32 ft wide to prevent particles of brine carrying over. It is also desirable to limit brine-spray pressure to about 10 lb, depending on the spray design, for the same reason. The use of a baffle curtain is also advantageous to prevent carry-over.

The brine temperature should be kept as high as practicable, consistent with obtaining the desired temperatures. Brine is frequently supplied from a central chilling system and usually varies in temperature, being warmer during the heavy refrigerating load periods. Brine temperatures also vary for different plants. Considering the probable variations in refrigeration load and refrigerant temperature, the spray system should be designed for flexibility. For a brine temperature of 15 to 20 F it is good practice to install brine sprays on the basis of approximately 2.25 gal per min per 1,000 lb of dressed hogs. The capacity of different makes of sprays varies, but is usually in the range of 1 to 1.25 gal per min per spray head for 8 to 10 lb per sq in. pressure. At least two brine spray headers correctly arranged should be used to obtain proper air circulation and provide flexibility in operation. Brine should have a salometer reading as low as consistent with the temperatures used, since salt has a hygroscopic effect. The air ducts should be proportioned correctly to insure proper air circulation.

Great care must be taken toward the end of the chilling period, with this type of system, since the desired air circulation is not always easily balanced with the refrigeration required. This is particularly true when the hogs are chilled to the desired temperature before cutting time, or if they are carried over until the next day. This disadvantage may be overcome by providing facilities for the recirculation of some or all of the brine without chilling it, as shown in **Fig. 4.** Humidity is also more easily controlled with the use of the recirculation feature. With this type of system it is important that the largest hogs be placed on the cold air side of the cooler to insure even chilling.

2. **Overhead decks with direct expansion ammonia coils and brine sprays** are also used. The sprays should be arranged so as to keep the coils thoroughly defrosted and provide proper air circulation,

as in **Fig. 6.** After passing over the coils, the brine is simply collected and pumped back to the sprays. Due to the resistance of the coil to air circulation, slightly more brine will be required than in system 1; however, since the coils tend to break up the brine spray, slightly higher brine pressure may be used without causing carry-over, and the number of sprays, therefore, may be the same as in system 1. On the basis of 25 lb per sq in. suction pressure, it is good practice to install one lineal foot of 2-in. direct-expansion ammonia pipe to 6 cu ft of total cooler space (approx. 70 ft per 1,000 lb of hogs). This system provides better control of humidity and air circulation than system 1, unless the latter is equipped with brine recirculating facilities.

3. **Unit coolers** may be either the straight brine-spray type, or they may be equipped with ammonia coils with brine defrosting and may be installed with or without an air-delivery duct system **(Fig. 7).** If the units can be properly placed in the cooler, satisfactory air distribution may be obtained without an air-delivery duct system by allowing approximately 2 ft 6 in. above the rail-supporting beams, to serve as a plenum chamber. If the room is long and narrow, e.g., 16 ft wide and 80 ft long, an air-delivery duct is required for proper air distribution. No return air-duct system is required in either case. The units should be provided with two-speed motors and dampers in the air outlets so that the amount of air circulation may be regulated as required. The use of suction pressure regulators with the ammonia-coil type units, and the use of brine-recirculating facilities with the straight brine-spray type units, will assist in proper humidity control.

The initial cost of a unit cooler installation is less than that of systems 1 and 2 utilizing overhead decks, and less building space is required. While there are relatively few unit cooler installations in hog coolers, their use is increasing.

Beef Chilling Methods

During dressing operations on the killing floor the carcasses are split in two. Generally each side of the better grades of beef is covered on the outside (skin side) with

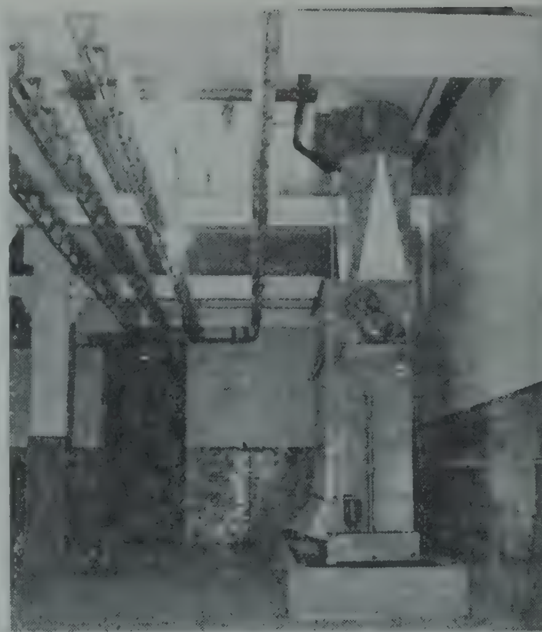

Fig. 3. Typical Unit Cooler Installation in a Beef Chilling Cooler, Utilizing the Space above the Rail Supporting Timbers as a Plenum Chamber.

cloth soaked in weak brine at 120 F. This is done to help minimize cooler shrinkage and to improve appearance. The internal temperature of beef carcasses entering the cooler is approximately 100 to 106 F. The specific heat is about .70 to .77. The dressed weight of whole carcasses will vary from around 400 lb to 1,000 lb, although some will be lighter and some heavier; the average weight is approximately 500 lb.

It is good practice to provide sufficient refrigerating **capacity** to obtain the following 18-hr maximum internal round temperatures for various weight carcasses:

400 lb	45 F
600 lb	50 F
800 lb	55 F
1,000 lb	60 F

The opening cooler air temperature should be approximately 31 to 32 F and at the peak of the refrigeration load should not exceed 36 to 38 F. The temperature should be brought back to 31 to 32 F as soon as possible after loading and held there.

It is essential that sides be placed on the rails so that they do not touch. Desirable average spacing for carcasses averaging 500 lb dressed weight is 15 in. center to

center of sides and is decreased or increased somewhat for lighter or heavier beef. Rails are usually spaced on 42 to 48 in. centers.

The Meat Inspection Division of the Department of Agriculture requires the rail height to be 11′-0″ for new plants engaged in interstate commerce, though there are some existing installations with lower rails.

The rate and amount of refrigeration, as in the case of hog carcass coolers, depends mainly on the weight of the beef, the spacing, the chilling schedule and the rate of cooler loading. It is not unusual for all weights of beef to be chilled in the same cooler, and, if possible, the heaviest should be placed so as to come in contact with the coldest air.

In some plants special coolers are provided for heavy beef, i.e. 800 lb and over. In these coolers the sides are spaced on 18 to 24-in. centers. The opening cooler air temperature should be 25 to 26 F and at the peak should not exceed 36 F. Temperature should be brought back to 29 to 30 F as soon as possible, and held at that point.

Unless there are extenuating circumstances, beef is not shipped the next day after killing. It is desirable to hold it until at least the second day to obtain lower internal temperatures and firmer meat, which provide better carrying properties for shipment. The time between slaughtering and shipping beef varies considerably, but the average is about 72 hr. In some plants beef is held after the first 18 to 24 hr in separate holding or sales coolers, and in other plants in the chilling cooler, which is then operated as a holding cooler.

At the end of the 18 to 24-hr chilling period not only must the internal meat temperature be as specified, but the sides should be reasonably firm without any freezing, be dry on the surface, and have a bright color. It is important, of course, that shrinkage be kept to a minimum.

During the early stages of beef chilling, as in the case of hog chilling, the humidity in the cooler is very high due to the vapor from the hot carcasses. Rapid air circulation and a high rate of refrigeration are desirable for the same reasons as in chilling hogs. As the chilling progresses the refrigeration rate is reduced as required to adhere to the temperature schedules. At no time should the air circulation be stopped entirely, or the beef will become "sticky," and there may be a loss of bloom. Humidity should be maintained at approximately 85 to 90 percent to prevent excessive shrinkage.

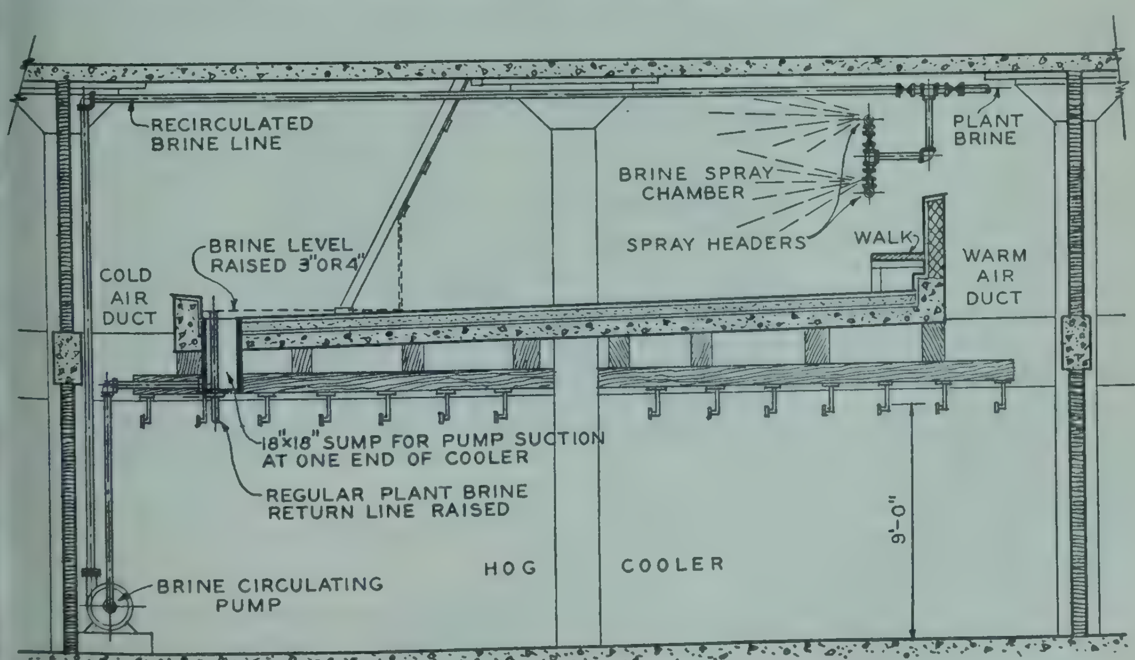

Fig. 4. Hog Cooler with Facilities for Recirculation of Brine.

There are many systems used for chilling beef. The most commonly used at present is the **overhead deck** with brine sprays, similar to the same type system used for chilling hogs. It is good practice to install brine (15 to 20 F) sprays to provide 2 gal per min per 1,000 lb of dressed weight. At least two correctly arranged brine spray headers should be installed to obtain proper air circulation and to provide flexibility in operation. The inclusion of the brine-recirculating feature provides better control of humidity and air circulation.

There are many installations where the coolers are not separated by partitions, making, in effect, one large cooler with a number of overhead deck spray systems (**Fig. 9**). In this type of installation the coolers usually serve as both chilling and holding coolers. Freshly slaughtered beef should not, if it can be avoided, be placed under a spray deck where chilled beef is hanging, since the vapor from the hot carcasses causes high humidity, which adversely affects the appearance and carrying properties of the chilled carcasses. If such placement is necessary, the chilled beef should be pushed to one end of the cooler and the warm beef placed in the other end. The required temperature control and refrigeration for each end can be maintained by having separate brine headers and spray systems for each half of the cooler. While the results of this type arrangement have been satisfactory, the trend has been toward separate chilling and holding coolers for better temperature, air circulation and humidity control—particularly for the chilled beef.

Unit coolers and the overhead deck system with direct-expansion coils and brine sprays are also used for beef chilling. If unit coolers are used, provision must be made for reduced air circulation, when the beef is held after chilling. It is important with unit coolers that there should be approximately 2 ft 6 in. above the rail-supporting timbers to serve as a plenum chamber.

When separate **holding coolers** are provided the beef is usually transferred from the chill coolers after 18 to 24-hr chilling. The holding-cooler temperature is usually maintained at 32 to 34 F, and there is some further chilling of the beef depending on how long it remains in the cooler. Rapid air circulation must be avoided since it would cause excessive shrinkage and discoloration. The air circulation should be held to the minimum required to maintain uniform distribution, correct temperature, desired relative humidity and to prevent condensation. The optimum relative hu-

Fig. 5. Smoked Meat Chilling Cooler in which Meats Are Chilled i[n] a Short Period of Time. Temperature of Room, 45 F; Direct Expansio[n] Ammonia Coils on Walls.

midity depends on the quality of the beef, the length of time held and the air circulation. Low humidity will cause excessive shrinking and high humidity may result in the beef becoming sticky or moldy. Relative humidity and air circulation must be considered together. Generally, the higher the air circulation the higher the relative humidity may be carried. For average conditions in a well insulated cooler a humidity of approximately 85 to 90 percent with about 12 to 15 air changes per hr will give satisfactory results.

Holding coolers may utilize any of the three refrigerating systems mentioned. In the overhead-deck-spray system it is advisable to provide brine-recirculation facilities to control refrigerant temperature as an aid in maintaining desired humidity and circulation. This control is provided in the overhead-deck system with ammonia coils and brine sprays. Two brine-spray headers separately controlled should be provided, and the sprays should be spaced to obtain the desired air circulation. Unit coolers may be used with or without air delivery ducts. If the shape and construction of the cooler are such that the units may be properly located, satisfactory air distribution may be obtained without an air delivery duct system by allowing approximately 2 ft 6 in. above the rail-supporting beams to serve as a plenum chamber. If the units are the straight brine-spray type, facilities should be installed for recirculation of some or all of the brine to assist in humidity control. For the same reason units which are equipped with ammonia coils and brine sprays, should have suction pressure regulators installed on the suction lines.

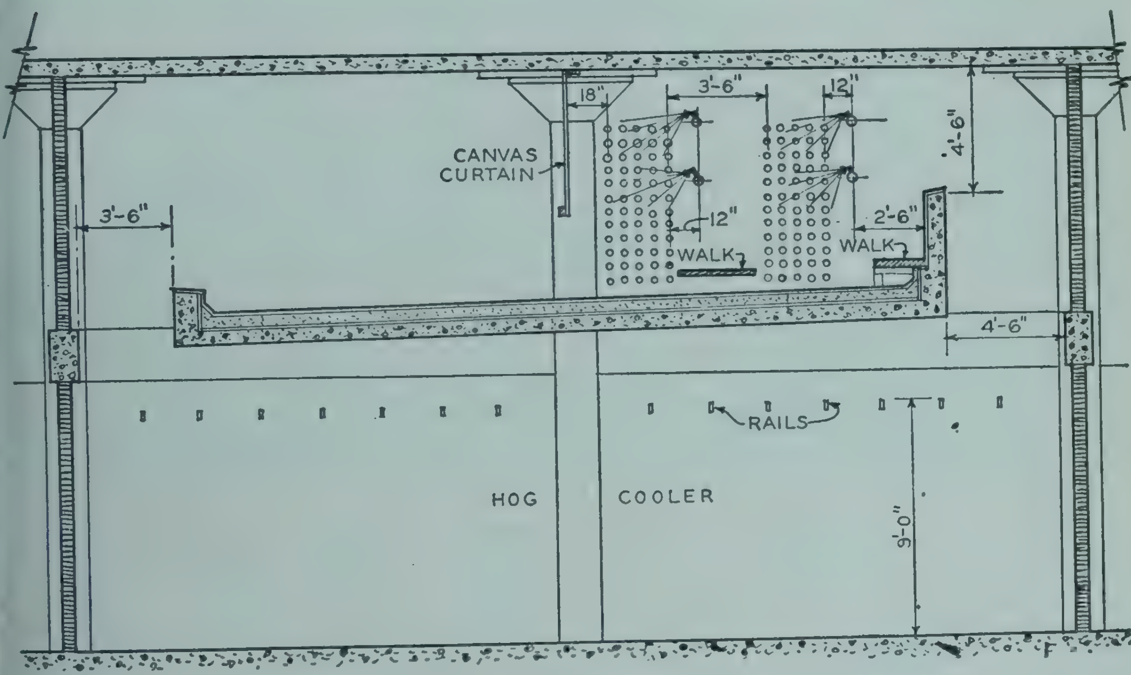

Fig. 6. Hog Cooler with Direct Expansion Coils.

Chilling Lambs and Calves

The internal temperature of lamb carcasses entering the chill coolers is approximately 97 to 101 F. The specific heat is approximately .66 to .74. The dressed weight will vary from approximately 20 to 120 lb, though the average is about 41 lb. They are readily chilled to an internal temperature of 33 to 34 F by the next morning or before. Lamb carcasses are frequently hung on logs—10 to a log—either single or double-decked **(Fig. 10)**. The carcasses should not be allowed to touch. At the

end of the chilling period they should be firm, without any freezing, and dry on the surface. Lambs are frequently shipped 24 to 30 hr after slaughtering.

The internal temperature of calves entering the carcass chill coolers is approximately 100 to 104 F. The specific heat is about .70 to .77. The dressed weight varies widely. For instance, in the dairy country the variation is from 70 to 110 lb, averaging about 90 lb; in the Midwest from 75 to 225 lb, averaging 150 lb; and in the Southwest from 125 to 275 lb, averaging 200 lb. Calves are often chilled hide on, and it is satisfactory practice to chill them to an internal temperature of 40 to 50 F, depending on size, in 18 hr. If they are to be skinned, it is frequently done after 24 hr in the cooler, or just prior to shipping. It is considered good practice by some to hold calves in the coolers, hide on, for 48 hr to improve appearance. They should be spaced on the rails so as not to touch. Spacing will vary from 10 in. for small calves to 24 in. for large ones. The spacing of the rails may be the same as in hog coolers.

Satisfactory opening air temperatures for either lamb or calf coolers is 33 to 34 F. It is desirable to provide sufficient refrigerating capacity to limit the air temperature at the peak refrigeration load to 38 F, and it should be brought back to 33 to 34 F as quickly as possible and held there. As in all carcass coolers, the humidity is high during the early stages of chilling, due to the vapor coming from the hot carcasses, and rapid air circulation is desirable during the early stages of chilling to remove the vapor quickly and prevent condensation.

As the chilling progresses the refrigeration rate is reduced as required. At no time should the air circulation be stopped entirely. In the case of lamb coolers stopping it would produce stickiness. After the carcasses are chilled, air circulation equivalent to approximately 12 air changes per hr. with a relative humidity of about 88 to 90 percent will be satisfactory.

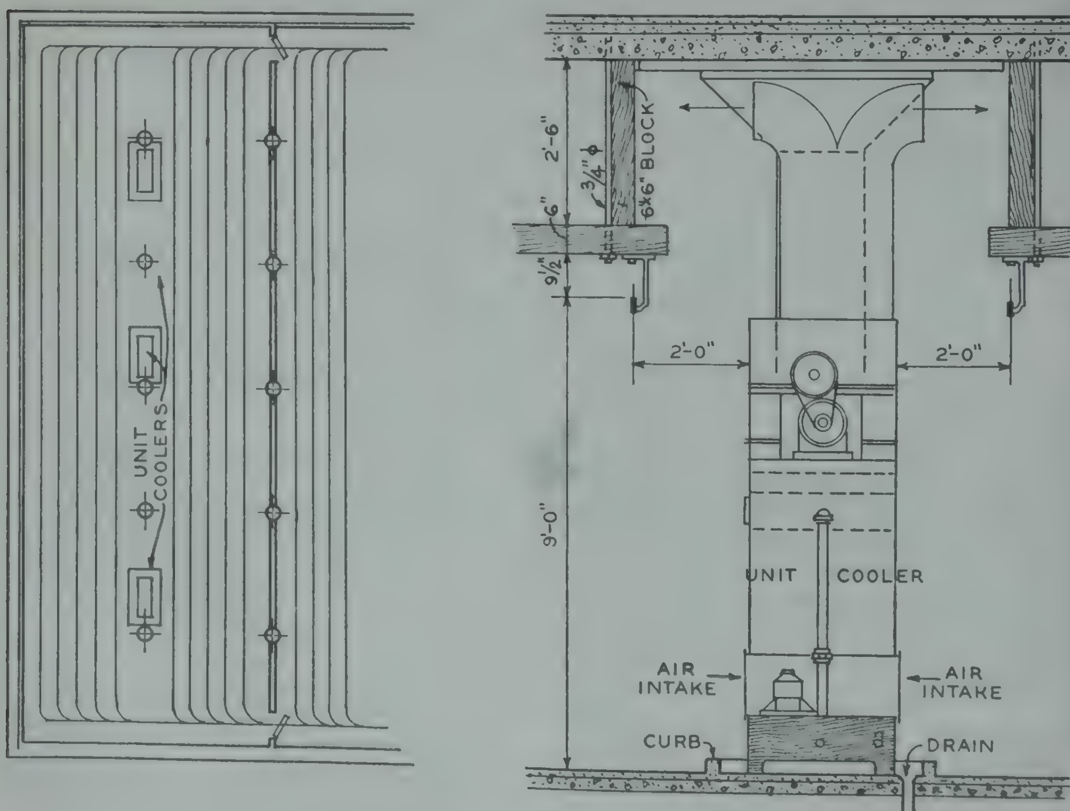

Fig. 7. Unit Cooler Adapted for Hog Chilling.

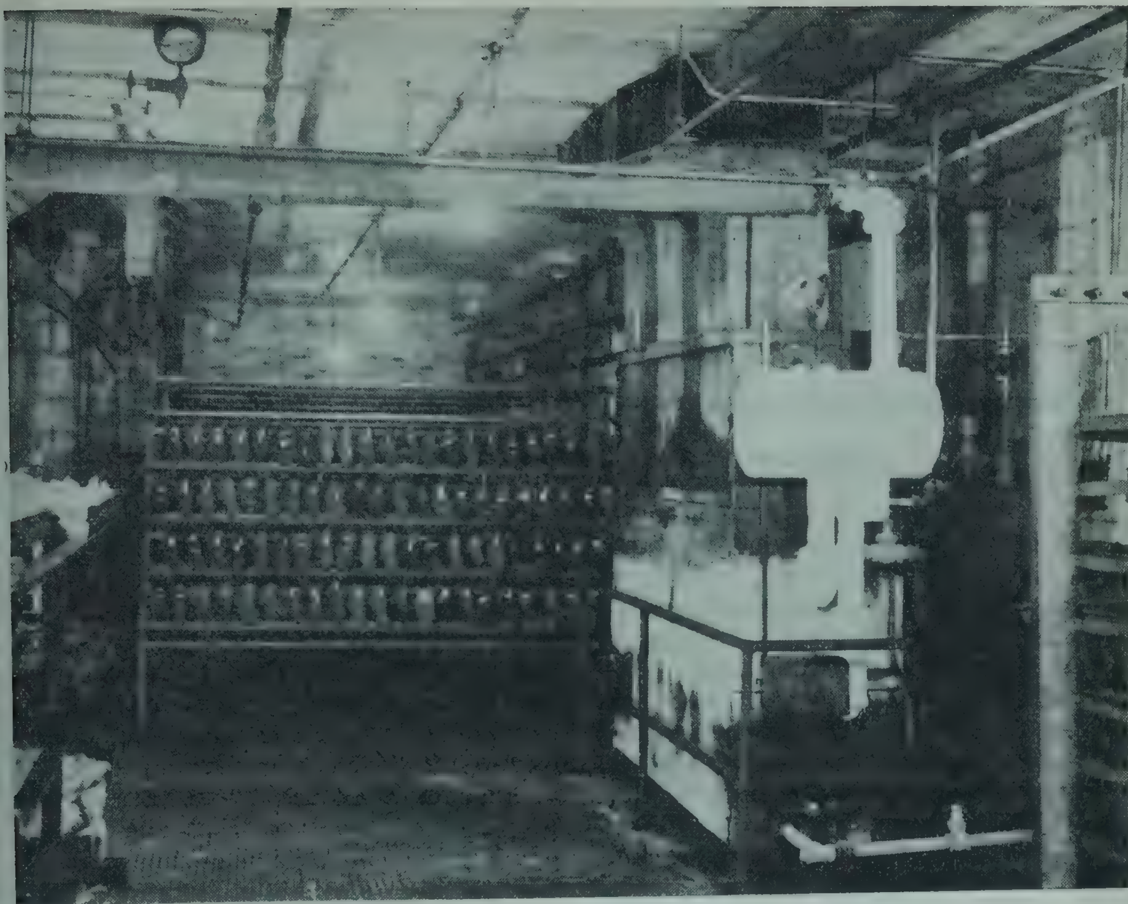

Fig. 8. View of a Fancy Meat Cooler Maintained at 32 to 34 F by Means of a Direct Expansion Unit Cooler Provided with Brine Defrosting. Unit Cooler is Equipped with a Suction Pressure Regulator. Temperature of Room is Thermostatically Controlled.

Any of the systems described for chilling hogs and beef may be used. The most commonly used at present is probably the overhead deck with brine sprays. For either lamb or calf coolers brine (15 to 20 F) sprays may be provided on the basis of 2 gal per min per 1,000 lb dressed weight. Two brine spray headers should be provided for flexibility. Brine recirculating facilities are desirable for maintaining the required air circulation when the refrigeration demand is very low, and for better control of humidity, especially in lamb coolers.

The overhead deck system with direct expansion coils and brine sprays and unit coolers may also be used for either lamb or calf coolers. If unit coolers are used, it is essential that the necessary reduced air circulation after chilling be obtainable. This is particularly essential in the case of lambs and may be accomplished by the use of variable-speed motors. It is important with unit coolers that sufficient space be provided above the rail-supporting timbers to serve as a plenum chamber.

II. PROCESSING COOLERS

Fancy meats. Warm meats are moved to the cooler as quickly as possible after trimming and washing as required. The temperature of these products when they enter the cooler will vary from about 80 to 104 F, averaging 90 to 95 F. Livers and tongues are usually hung on hooks, and other fancy meats are thinly spread on metal trays for chilling.

The cooler temperature is generally maintained at 32 to 34 F. Fairly rapid air

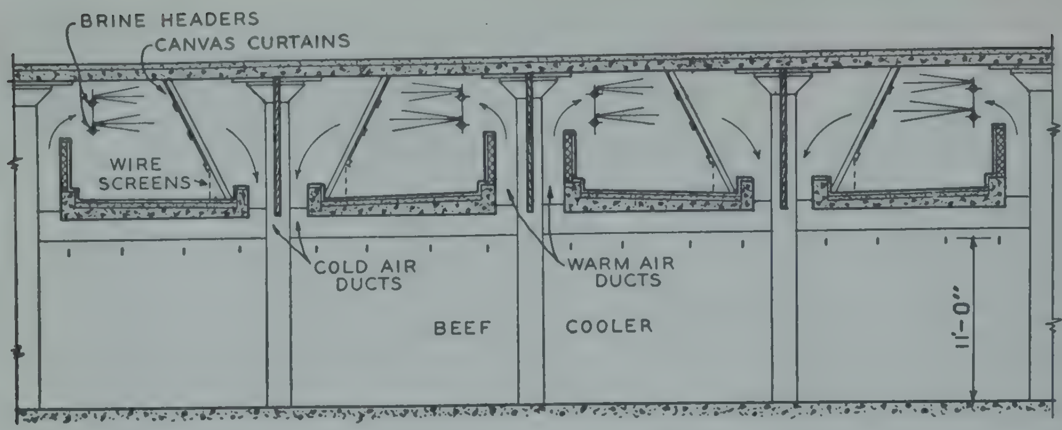

Fig. 9. Beef Cooler with Overhead Spray Systems.

circulation is required to remove vapor given off by the warm meats, to prevent condensation on the walls and ceiling, and to speed chilling. However, because of their small size they chill rapidly. The amount of air circulation required during the early stages of chilling depends on the extent to which the room is filled and the resulting refrigeration load. In a cooler that is loaded to capacity and where hooks and trays are used in the usual manner, good results can be obtained with air circulation equivalent roughly to 15 to 20 air changes per hr. As the chilling progresses, it is advisable to reduce the air circulation as the refrigeration load decreases to prevent discoloration and shrinkage. The humidity should be maintained at approximately 90 percent. If the products are held in the cooler after chilling, before they are packed, the air circulation should be kept at the minimum required to maintain the scheduled room temperature and humidity.

There are a number of methods in use for refrigerating fancy meat coolers, such as the overhead-deck brine-spray system; the so-called "indirect" system, in which air from the cooler is circulated by means of a fan through a cabinet containing brine sprays and located outside the room; and the unit cooler system. In the first two it is advisable to provide facilities for recirculating some or all of the brine, so that the brine temperature can be controlled to assist in maintaining the desired humidity. With the indirect system, delivery and return air ducts are usually installed in the cooler to obtain satisfactory air distribution. Unit coolers located in the fancy meat cooler are very satisfactory. They may be the straight brine spray type with provisions for brine recirculation or may be equipped with ammonia coils and brine defrosting facilities. If equipped with ammonia coils, the units should have suction pressure regulators so that the suction pressure may be kept as high as possible after the early stages of chilling and during the holding period, to assist in maintaining high humidity. It has been found that at this stage a suction pressure of 35 lb is satisfactory. Unit coolers should be equipped with two-speed fans. Air ducts are not required if the ceiling height is adequate to permit air distribution without allowing the air to blow directly on the product, or to cause drafts objectionable to people in the cooler.

Pork cutting. The temperature is usually maintained at approximately 45 to 50 F. A great many people are needed to handle the operations on the pork cutting floor. Most of them are furnished with a small container holding water at about 150 F, attached to the cutting tables, in which to immerse the knife or cutting tool to assist in the cutting operations. This hot water gives off vapor which must be removed for the comfort of the operators as well as to prevent condensation on the ceiling. Some air circulation is required for this purpose; however, the amount and distribution of air must be such that it is not objectionable

to the operators. It is advisable to keep the dew point of the room below the temperature of the hogs entering the cutting room from the chill coolers to prevent condensation on the carcasses or cuts. This may require some reheating of the air leaving the chilling apparatus. For a room temperature of 50 F and a dew point of about 30 F, the relative humidity would be approximately 45 percent.

Satisfactory conditions can be maintained by means of properly designed indirect systems using either ammonia coils with brine defrosting or merely brine sprays and utilizing delivery and return air ducts for proper air distribution. Good results may be obtained from unit coolers installed in the pork cutting room, but it is highly advisable to use air distributing ducts with properly designed outlets to insure satisfactory air distribution, which will not be objectionable to the operators.

Pork trimming. The temperature maintained is usually the same as that of the pork cutting floor, i.e. 45 to 50 F. Women are frequently employed in this work. Because they object to drafts even more than men do, it is important that the required refrigeration be provided with very little air circulation. Ordinarily hot water containers are not used. Satisfactory results may be obtained by the installation of wall coils—either direct expansion ammonia, or brine. Installations of refrigerating equipment using mechanical air circulation may be used satisfactorily, but as stated above, great care must be taken in providing air circulation and distribution that will not be objectionable to the operators.

Beef, veal, and lamb cutting and boning. The temperature in these rooms is frequently maintained at 36 to 38 F. A large number of operators is required and the avoidance of drafts is important. Hot water containers for knives are not generally used. It is desirable to keep the dew point below the temperature of the carcasses entering the rooms. Satisfactory conditions may be maintained with direct expansion or brine coils located on the walls. Unit coolers or other systems using mechanical air circulation are satisfactory, but, as in pork cutting and trimming rooms, drafts must be avoided.

Pork holdover. Pork cuts that are to be shipped fresh are usually packed on the pork cutting floor. If they are not shipped

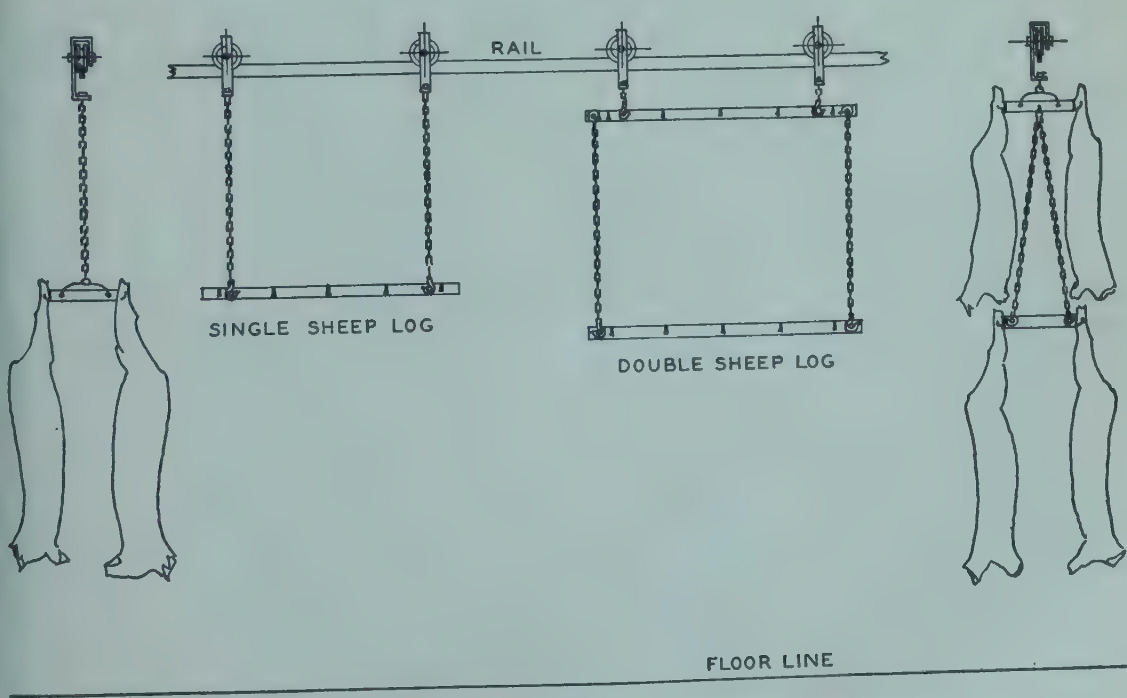

Fig. 10. Arrangements for Hanging Lamb Carcasses in Chill Cooler.

the same day they are cut and packed, they should be held in a cooler having a temperature of 26 to 28 F. Pork trimmings, also, that are to be held over should be kept in a room at 26 to 28 F. There is no particular advantage in providing mechanical air circulation. It is satisfactory to install direct expansion coils on the ceiling or walls of the cooler. If on the ceiling, it is preferable that the coils be placed over the aisles so that defrosting operations (usually with hot ammonia gas) can be performed without interfering with the product.

Pork curing cellars. Room temperatures ranging from 35 to 39 F, depending on the particular plant practice, are generally used for sweet-pickle, dry-salt, and dry curing. In sweet-pickle cellars round wooden curing vats of around 1,500-lb capacity are usually double-decked to use the maximum available room space. Product to be dry-salt cured is usually stacked on floor racks in the curing cellar. Bellies to be dry cured are placed in metal boxes stacked several high. Uniform temperatures throughout the cellars are important to insure even curing, since curing is more rapid at higher temperatures.

Curing cellars are usually equipped with either direct expansion or brine coils. It is advisable to install the coils on the ceilings over the aisles so they may be defrosted without interfering with the curing operations. Due to warm air entering the cellars when doors are opened, condensation is likely to collect on the ceilings and drip on the product or into the curing vats. It is important that sufficient insulation be provided between curing cellars and rooms above, if they are at lower temperatures than the cellars, to prevent condensation on the ceilings. Some mechanical air circulation could be used to advantage to prevent condensation and to assist in obtaining uniform temperatures.

The pickle used in sweet-pickle curing is usually made up and chilled in rectangular wooden vats located in a separate room. It is chilled to the curing cellar temperature.

Smoked meat coolers. Practice varies widely in the handling of meats after smoking. Satisfactory results may be obtained by placing the smoked meats, a few hours

Fig. 11. Sliced Bacon Packing Room Maintained at Approximately 50 F by Means of a Direct Expansion Unit Cooler with Brine Defrosting Facilities.

Fig. 12. Typical Meat Packing Plant Freezer with Overhead Flooded Type Ammonia Coils —Temperature Maintained at Approximately 0 F.

after smoking, in a cooler with a relatively high temperature for partial chilling. They may be wrapped in this cooler, then transferred to a lower temperature cooler and held until shipped. In the first cooler a temperature of 45 to 50 F is satisfactory. It is important, of course, that shrinkage be kept to a minimum. Since rapid air circulation tends toward the opposite results of high humidity in regard to cooler shrinkage, it is necessary to assure proper relationship between the two. It has been found that good results may be achieved by simply installing refrigerating coils, either brine or ammonia, in the cooler in such manner as to obtain reasonably uniform temperatures and have only the natural air circulation due to the coils.

A satisfactory temperature for the storage of the wrapped smoked meats is 28 to 32 F. Required refrigeration may be obtained satisfactorily by the use of coils.

Sliced bacon. Bacon for slicing is first chilled, usually overnight, on smoked-meat trees in a railed cooler held at a temperature of 24 to 28 F. Generally, refrigeration is supplied by direct expansion ammonia coils. After chilling, the bacon for slicing should be very firm but not frozen, and have an internal temperature of 28 to 32 F.

The slicing room is usually held at a temperature of approximately 50 F. It is advisable to maintain the dew point of the room air below the temperature of the sliced bacon to prevent condensation of moisture on the product, as it would be conducive to bacterial action. Considering that the temperature of the sliced bacon may be 30 F, it is advisable that the humidity be maintained below 45 percent.

There are a great many operators, mostly women, in a bacon slicing room; therefore the air circulation and distribution must be such that there will be no objectionable drafts. Slicing rooms are frequently refrigerated by means of a brine spray cabinet, usually outside the room, through which the room air is circulated for chilling. With this type of installation, delivery and return ducts are provided in the slicing room for proper air distribution. Unit coolers installed in the room may be used satisfactorily.

Sausage. Raw materials used in making smoked and cooked sausage are hashed, formulated, chopped, and spices and curing materials added in a cooler maintained at a temperature of 36 to 38 F. Since the sausage is usually stuffed immediately after these operations, the humidity in the grinding and chopping cooler is not particularly important. However, a humidity of 70 to 80 percent is satisfactory. The cooler may be refrigerated by brine or direct expansion coils, though it is often necessary to provide circulation and distribution of air not obtainable with coils in order to prevent condensation on the ceiling. For this reason, unit coolers or other indirect systems are more suitable than coils.

After smoking and cooking, the sausage has an internal temperature of approximately 150 to 160 F and is usually chilled in a cold water spray to 100 to 120 F. It is then hung on racks in the sausage packing cooler maintained at 45 to 50 F. It is good practice to pack and ship the sausage the next day, but even with this short holding period, it is important that humidity and air circulation be properly controlled to keep the sausage in good condition. Rapid air circulation and low humidity must be avoided to prevent wrinkling of the product due to excessive shrinking. High humidity and insufficient air circulation may result in the product becoming clammy. Experience has shown that a relative humidity of 88 to 90 percent is satisfactory. The amount of air circulation should be the minimum required to maintain uniform air distribution, required temperature and desired relative humidity.

The ingredients of fresh pork sausage are usually hashed and mixed in the same cooler used for smoked and cooked sausage. After stuffing it is sprayed with cold water, then placed in a wind tunnel held at a temperature of 24 to 26 F in order to dry the surface and chill the product to an internal temperature of 36 to 38 F. It is good practice to pack the sausage as soon as it comes from the wind tunnel in a cooler held at 40 to 45 F. After packing, it is placed in a freezer at 0 F and hard-chilled before shipping.

Lard. After rendering and settling, lard is usually quick-chilled to obtain a smooth product. Ordinarily the chilling is done on a cylindrical roll approximately 9 ft long by 4 ft in diameter and operated at 9 to 14 rpm, which may be refrigerated by either brine or ammonia inside the roll. Brine temperature of about 15 F or ammonia at a suction pressure of about 20 to 25 lb is satisfactory. The lard, at approximately 125 F, is fed on the roll in such a way as to maintain a thin film on the cold surface. The chilled lard is removed from the roll after slightly less than one revolution by means of a scraper. It is chilled to approximately 68 F. The cooling may also be accomplished by Votator equipment. It is then packaged and stored in a cooler maintained at a temperature of 45 F. Refrigeration for the cooler can be supplied satisfactorily by means of brine or ammonia coils.

Assembly cooler. Products are usually packed in their respective department coolers and assembled for shipping in a room, located at dock level, ordinarily maintained at a temperature of 36 to 38 F. Unless some products are packed in this cooler, as may be the case in smaller plants, humidity control is not particularly important. The traffic into and out of an assembly room is very heavy, and, unless sufficient air circulation is maintained, condensation is likely to collect on the ceilings due to warm air entering the cooler. For this reason it is advisable to provide positive and uniform air circulation. Unit coolers are readily applicable to this type of service.

Freezers. Generally, meat products to be frozen are packaged to prevent excessive shrinkage, freezer burn and discoloration. The types of freezers and the temperatures used may vary considerably. The conventional freezer is refrigerated by means of ammonia coils (direct expansion, flooded, or recirculating type) or by calcium-brine coils installed just below the ceiling and/or on the walls. Packaged products, varying in weight from about 25 to 150 lb, are spaced for freezing. Frequently, portable airplane fans are used to

circulate the air through the packages and over the coils to accelerate freezing. In some cases packaged meats are frozen on shelf-type refrigerating coils.

Satisfactory results may be obtained by freezing products in 0 to −10 F temperature. The closer the refrigerant temperature is to the room temperature, the higher the humidity will be. The more coil surface installed, the closer the two temperatures will be. There are practicable limits to the amount of coils that may be installed from the standpoint of cost and space required. It is good practice to install direct expansion piping on the basis of 1 lin ft of 2-in. pipe to 3 cu ft of freezer space, for a suction pressure of 5 lb.

The product may be piled for storage in the same freezer in which it is frozen or it may be moved to a storage freezer. Storing in the same room frequently results in reduced labor costs. Most frozen meat products may be satisfactorily stored for the usual holding period in 0 F temperature.

The use of quick freezing units is increasing. These are usually designed so that flat-top trucks or skids of packaged meats, properly spaced, may readily be moved in and out. Temperatures maintained are from approximately −35 to −50 F, with very high air velocities, say 500 ft per min or higher. While the unit cost of refrigeration is much greater for these units, there are some definite advantages to be gained, such as reduced labor costs, less building space required as compared to the conventional freezer, quicker turnover of product, and probably improved products.

General. The ammonia compression system is most often used in meat packing plants, the number and capacity of compressors being determined by the refrigeration load of the individual plant. This may vary from 100 tons or less to 4,000 tons or more. Ordinarily, motor and steam-engine drives are used, the selection depending on the cost of power and steam, the initial cost and the low-pressure steam requirements of the plant. As a rule, two suction pressures are used, one for freezers, usually 0 to 5 lb per sq in. gage and the other for coolers, usually 20 to 25 lb per sq in. gage. Where very low temperature quick freezing units are used, a third and lower suction pressure is required. The booster system is generally used for freezer work.

Because of the considerable use of direct expansion ammonia coils operated manually, and the rapidly fluctuating load peculiar to a meat packing plant, it is good practice to install ammonia accumulators on both freezer and cooler suction lines to trap out entrained liquid ammonia, or possible slugs of liquid ammonia. The accumulators should be equipped with pumps for returning the ammonia liquid to the high side receivers or, if practicable, to the low side. The ammonia condenser equipment may be any of the conventional types, depending largely upon the amount, temperature and kind of water available. Large quantities of sodium chloride brine are usually required, as indicated in the foregoing discussion, and may be chilled in shell-and-tube type coolers, or in various types of brine tanks. It is desirable, from the standpoint of economy, that these be operated flooded and float-controlled. The brine for the entire plant may be supplied from one central system, or from several separate systems. While the practice varies among plants, the average brine temperature is usually between 15 and 20 F.

It is very important that packing-house coolers and freezers be well insulated and have as few doors as operations permit. While the elimination of insulation between coolers of different temperatures may not result in a loss of refrigeration, frequently it is required to prevent condensation in the higher temperature coolers, or to assist in the control of humidity.

If you searched this chapter for something which was not found in it, please let the editors know.

25. MILK PLANTS

REFRIGERATION is used in milk plants to maintain temperatures low enough to inhibit the extremely rapid growth of bacteria otherwise taking place. An indication of the effect of temperature on the rate of bacteria growth is given in **Table 1.** The application of refrigeration to three types of plants, country cooling station, market milk plant and condensery, is considered here.

Table 1. The Growth of Bacteria in Milk in Various Periods

Temp, F	Time, hours 24	48	96	168
32	2,400	2,100	1,850	1,400
39	2,500	3,600	218,000	4,200,000
46	3,100	12,000	1,480,000	
50	11,600	540,000		
60	180,000	28,000,000		
86	1,400,000,000			

The Country Cooling Station

Health regulations usually require that milk be received at a cooling station not later than 9 a.m., while farmers' habits make it necessary to open the station at 6 a.m. Farmers some distance from the plant may subscribe to a trucking service, and it is desirable to schedule trucks to avoid simultaneous arrival, but peaks must be expected. The maximum cooling rate is influenced by many conditions such as the willingness of the farmers to cooperate, habits of the truck drivers, and the general routine of the neighborhood. **Table 2** shows the practice for a group of actual plants.

The speed at which the can washer operates limits the rate at which cans are dumped, and thus establishes the maximum **rate of flow** over the cooler. Thus, in a plant equipped with a 14-can-per-minute washer, the maximum rate of flow is 140 gal per min, assuming 10-gal cans are used, and assuming further that the cans are full. Actually the average rate of dumping may be more nearly 13 cans per minute and the average content of the cans may be found to be approximately 8 gal each.

The milk received is from the same morning's milking and the previous night's, the latter having been cooled by the farmer to a temperature of 50 F to 60 F as required by public health regulations. The morning's milk may arrive at the station close to the animal body temperature of 98 F. The temperature of the mixture, after dumping in the plant, seldom exceeds 78 F. Cold water from wells, springs or creeks is used wherever possible to precool the milk before it comes into contact with the refrigerant cooler. The plants listed in Table 2 are equipped

Table 2. Capacity of Cooling Stations, Operation 6 to 9 a.m.

Plant	No. of gal of milk per day	Number of shippers	Refrigeration requirements in 3 hr, tons
A	3,684	128	17.8
B	3,738	112	18.2
C	2,830	88	13.8

CARL A. BLANCHARD, JR., Author Chapter 25. Educated at Tufts College, Medford, Massachusetts. Dairy Engineer, H. P. Hood and Sons, 1938 to date. Registered Professional Engineer.
At present, Assistant Director of Engineering, H. P. Hood and Sons, Boston, Mass.

with wells yielding water at a temperature of about 56 F. The milk temperature as it strikes the ammonia section of the cooler can be designed for 60 F. The usual regulations require that milk be delivered to the market milk plant from the cooling stations at a temperature not to exceed 40 F. This means cooling to about 37 F.

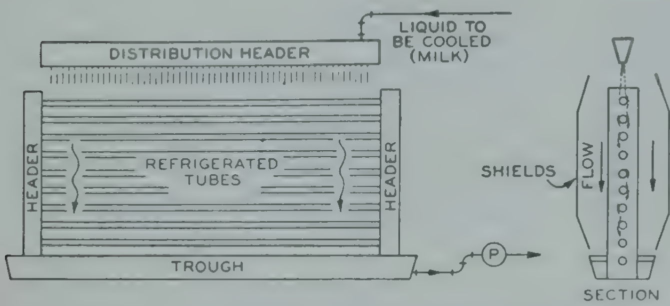

Fig. 1. Functional Diagram of Surface Cooler.

Since the cooling load in these plants averages only about three hours' duration in twenty-four, careful consideration should be given to the type of refrigeration equipment to be used. The decision lies principally between direct expansion systems employing gravity flooded coolers with large capacity compressors and stored refrigeration systems employing ice build up tanks, plate coolers and small capacity compressors. Each system has its advantages and disadvantages, and the peculiarities of each plant must be analyzed to determine which system is best suited for it.

Condensing water. If a supply of water is available at the rate of about 1.5 times the maximum flow of milk over the cooler, the water may be passed in series through the water section of the milk cooler and thence through the ammonia condenser with satisfactory results.

Example:

Temperature of milk as received, °F..	78
Temperature of milk leaving.......	60
Density of milk, lb per gal.	8.6
Temperature of water entering cooler	56

If the water flows through the cooler at the rate of 1.5 gal for every gallon of milk flowing over the cooler, then the rise in water temperature in °F is

$$\frac{1(78–60)\times 8.6\times 0.93}{1.5\times 1.0\times 8.33}=11.5°$$

The temperature of water entering the condenser thus is $56+11.5=67.5$ F. The rise in temperature of the water flowing through the condenser is

$$\frac{1\times 8.6\times 0.93\times (60–38)\times 1.25}{1.5\times 8.33}=17.6 \text{ F}$$

where 1.25 is a factor which allows for the heat of compression. The temperature of water leaving condenser is $67.5+17.6=85.1$ F.

This indicates the possibility of operating the system at a head pressure not exceeding 175 lb per sq in. gage under conditions of maximum load with ammonia.

Where cold water is not available in this proportion a different arrangement for condenser water must be found. A cooler designed to reduce the milk temperature to within 4 F of the entering water temperature is not practical unless the flow of water is at least equal to the flow of milk. If the available flow of well water is less than the flow of milk, sufficient water can be stored for use at the required rate during the 3 hr of plant operation.

Design details. 1. Direct expansion systems. The more efficient of these systems consists of a cabinet cooler as the evaporator and a large capacity compressor and condensing system.

The cooler consists of water and ammonia sections made of stainless steel. The ammonia section is fully flooded with gravity controls consisting of a surge drum with a float valve to maintain a constant liquid level and a pressure control to maintain as high a back pressure on the cooler as practical to prevent the freezing of milk on the cooler during periods of light load. For operating economy it is often practical to employ a surge drum with reserve holding capacity equal to the volume of the cooler leaves so that during the wash-up period the ammonia can be blown back into it instead of having to operate a compressor to evacuate the cooler. The heat transfer value of cooler leaves fully flooded with liquid has been found to lie between 150 and 200 Btu per hour/sq ft/°F temperature difference.

The compressor should fit the capacity of the cooler so as not to pull too low a suction pressure. An oversized compressor is a waste. It should be operated automatically with a suction pressure switch, for in a receiving plant the flow of milk is erratic and there are periods when the compressor might operate in a vacuum and thus draw in air, pump oil, and use unnecessary power.

2. Stored refrigeration systems. The plate cooler, ice build up unit, and small capacity compressor and condensing system make up one of the best systems of this type in use today.

The plate cooler consists of a press containing a number of gasketed stainless steel plates. It may be assembled with a water section and an ice water section. The heat transfer in a plate cooler has been found to lie between 300 and 400 Btu/hour/sq ft/°F temperature difference.

Ice water is provided by an ice build up tank consisting of a large water reservoir in which are submerged fully flooded ammonia coils. Controls for the coils consist of a surge drum with a float valve to maintain a constant liquid level. Ice is allowed to form around the coils to a predetermined thickness. The thickness of the ice, and hence the amount of ice, can be regulated as required by adjustment of the controller.

The compressor is operated automatically by the controller measuring the thickness of the ice build up. It should be sized to the capacity of the ice build up unit so as to operate on as high a suction pressure as practical.

This system is little troubled by the erratic flow of milk over the cooler in a receiving plant. It is wise to tie the operation of the ice water circulating pump in with the milk pump so as to stop the circulation of ice water when no milk is flowing.

The Market Milk Plant

The refrigeration requirements in a market milk plant may be classified as follows:

- Cooling of raw milk
- Cooling of pasteurized milk
- Cooling of by-products
- Cooling of refrigerator boxes
- Ice making
- Air conditioning.

Cooling of raw milk. Most plants receive raw milk both in tank trucks from cooling stations and in cans directly from farmers. The tank truck milk requires no further cooling at the city plant. The milk in cans arrives at a temperature generally fixed by regulation at a maximum of 60 F. Farmers must thus cool both the night and morning milk to an average temperature seldom exceeding 55 F.

It is considered good practice in the city plant to cool the raw milk at once to 40 F in a manner similar to that described above, interposing a milk cooler between the storage tanks and the receiv-

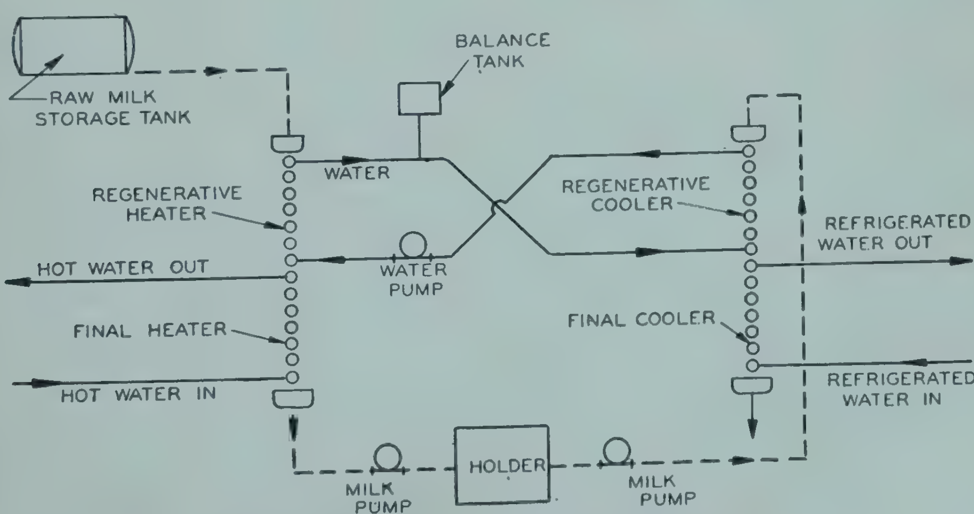

Fig. 2. Milk-to-Water Regeneration System.

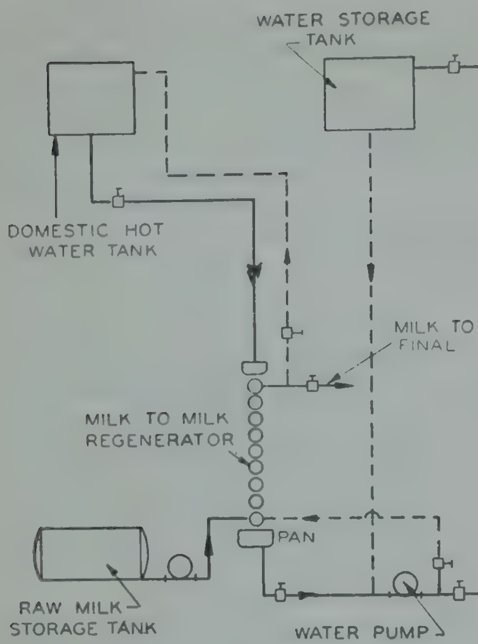

Fig. 3. Arrangement for Use of Hot Water for Preheating.

ing vat. It may be done, however, with the use of cold wall tanks employing ammonia, Freon, ice water or brine in the jacket. Another type of equipment in common use is a tank cooler or horizontal tank with an immersed stainless steel direct-expansion coil.

The rate of cooling in these tanks is given by manufacturers as follows:

Jacketed tank 3000 gal, 50 to 40 F in 1 hr with glycol at 18 F.

Coil tank 5000 gal, 60 to 40 F in 3 hr with ammonia at 25.8 F.

Cooling of pasteurized milk. The most widely used method of pasteurizing milk consists of heating to 144 F, holding at this temperature for 30 min and cooling to 36 to 38 F. The cold raw milk is usually heated in a heat exchanger by the returning hot, pasteurized milk. Economic design limits the extent of exchange to about 80 percent. The cold milk will be heated from about 40 to 123 F, and the hot milk will be cooled from 144 to 61 F. Then mechanical refrigeration reduces the temperature from 61 F to the bottling temperature of 36 to 38 F. A plate type regenerator in combination with a final heater and cooler (milk-to-milk regeneration) has been perfected for this job.

Another type of system commonly used is known as **milk-to-water regeneration** as distinguished from the above system, which is known as milk-to-milk regeneration. The milk-and-water flow through this type of plant is shown in **Fig. 2.** The equipment is similar to the surface cooler. Two exchanges of heat are required, the first from milk to water and the second from water to milk. Economic design allows a high percentage for each exchange, with the result that the raw milk is heated from 40 to 122 F on the regenerative heater (with the addition of external heat to the water circuit) and the pasteurized milk can be cooled from 144 to 71 F on the regenerative cooler. In spite of the reduced efficiency of this system, many operators prefer it to the milk-to-milk system because of the rapidity of heating and cooling, the opportunity for thoroughly aerating the milk, and the lack of the necessity for pumping milk under pressure. In order to reduce the load on the refrigerating plant, cold water from a well or other source of supply is pumped through a cooling section interposed between the regenerative cooler and the final cooler. Where water is available at 56 to 57 F in sufficient quantity, the milk can be reduced to 61 F before coming in contact with the final cooler, in which case the demand on the refrigerating plant is the same as where milk-to-milk regeneration is used.

In the operation of a pasteurizing system requiring a 30-min holding period, about 35 min are required to fill the equipment with milk, with the result that hot milk is not available for regeneration until after this period, and likewise cold milk is not available for regeneration during the final 35 min while the equipment is being emptied. To precool the hot milk, water is substituted for the cold milk in the regenerative cooler. Where the temperature of the available water supply exceeds 65 F, considerable increase in load will be felt.

Fig. 3 shows an arrangement which makes possible the use of hot water for preheating at the start of the day's operation and cold water for precooling at the

finish. Hot water at 144 F, in passing over the regenerator, is cooled to 61 F and stored in a tank where it is further cooled to 40 F. During the final 35 min of operation this water is pumped through the regenerator, is heated to 123 F and stored in the domestic hot water tank for later use in the plant.

In the Short-Time-High-Temperature (S-T-H-T) method of pasteurizing, milk is heated to 161 F and held at this temperature for a period of 15 sec before being cooled to bottling temperature. The same types of regenerators are employed as are used in the 30-min holding system. In the milk-to-milk regenerator, raw milk is heated from 40 to 136 F and pasteurized milk is cooled from 161 to 65 F. In the system employing milk-to-water regeneration, raw milk is heated from 40 to 136 F on the regenerative heater, and pasteurized milk is cooled from 161 to 80 F on the regenerative cooler.

Cooling of by-products. Because of the relatively small quantities involved, products like cream, chocolate milk and buttermilk are processed in batches. One type of batch tank has a jacket made by continuously welding angles on the outside of the inner liner in a manner to form a spiral raceway around the tank. These tanks are provided with agitators, the blades of which are arranged to scrape the product from the side of the tank as the agitator revolves. The **buttermilk** process consists of heating to 170 F and holding at this temperature for 30 min for pasteurization, cooling to 70 F, introducing the culture and allowing it to incubate for about 16 hr, and then cooling to 40 F for bottling. This can all be done in a vat of this type by arranging to circulate successively a heating medium and one or more cooling mediums. A spray-type jacketed tank is also used for this. The initial cooling from 170 to 70 F can be done by pumping well water through the jacket.

The usual operation allows about 1 to 1½ hr for this process and manufacturers usually proportion the surface to accomplish this with 56 F well water.

Although **cream** is often cooled in the same vat in which it is pasteurized, most operators prefer to cool it rapidly over a surface cooler. In cooling **chocolate milk** the choice is between a tank and a surface cooler, depending on the ingredients used.

Cooling of refrigerator boxes. In many plant operations, products are bottled during the day and put in a refrigerated storage room for delivery the following morning. It is of great importance to keep this room at a temperature close to 32 F, during the period in which the cream rises, as temperature affects the volume. It is also desirable to put the milk on delivery trucks at this temperature. For the purpose of calculating the area required for storage of finished products, **Table 3** gives the dimensions of various kinds of cases and the heights to which they can be conveniently stacked. It is not unusual to allow additional space equal to the area actually required by the cases to provide for conveyors, working aisles, unit coolers and for sorting miscellaneous products.

With the advent of square bottles, space requirements have been reduced by about 25% below those indicated in Table 3.

Table 3. Dimensions of Milk Cases for Round Bottles

Kind	No. of bottles per case	Dimensions, in.	No. of cases high
Quart	12	18½×14×10¾ high	5
Pint	20	18½×14×9 "	6
Half-pint	30	18½×17×7½ "	8
Gill	30	18½×14×6 "	9

The **load** is made up of heat leakage through walls, ceiling and floor; heat generated by lights, motors, workmen and heat introduced by fresh air, wash water, cases, bottles and their contents. The heat introduced by cases, bottles and their contents accounts for a considerable portion of the total load. The products are usually cooled to not lower than 37 F for bottling since lower temperatures cause foaming in the filling operation. It has been found that the heat gain of the product due to its exposure to filling room temperature during the time required to pass from the cooler into the bottle and thence into the cold storage room, plus

the heat extracted from the warmer bottles, causes the temperature of products to rise about 3 to 5 F, depending on conditions of operation. Cases may enter the cold storage room at a temperature as high as 85 F, depending on conditions in the empty case storage room and on the temperature of the water used in washing the cases. Since the heat load per cubic foot of space in the refrigerator is necessarily great, a system employing mechanical **circulation** of air gives the best results.

Because of the large moisture load present, it is of the utmost importance to provide a means for **defrosting** the cooling coils. **Fig. 4** shows the application of a warm brine defrosting system as installed in two large dairies employing brine as the cooling medium. Operators should be instructed to defrost each set of coils once a day during the summer season. City water is allowed to flow over the brine heating coil, and the defrosting brine is recirculated through the heating coil and through the unit which is being defrosted by means of the defrosting pump. The entire operation is completed in very few minutes.

Cooling of products during delivery. Ice is used to keep the products cool while on the delivery vehicle. In many plants the driver takes with him one or more pieces of ice weighing 100 to 150 lb, and it becomes his responsibility to distribute the ice over the cases in a way that will insure that his products remain cold during the delivery period and that those products which he returns to the plant are in satisfactory condition. In many cases vehicles are equipped with ice-cooled cabinets holding about six cases. Those products which are intended for late delivery and also those which are returned to the plant are put in these cabinets. Where it is thought desirable to relieve the driver of the responsibility for keeping the products cold, some form of prepared ice is placed directly on the product in the cases, in amounts varying between 10 and 13 lb per case during the hot weather. **Refrigerated trucks** for retail delivery of milk products have not been used to any great extent to date, although large refrigerated vans are used for transporting bottled milk between plants and distribution points.

Air conditioning is applicable to the visitors' rooms, general offices and drivers' rooms. It is desirable to zone the system to permit operating the portion serving the drivers' room as a separate unit. Ample allowance of fresh air in this room is recommended.

Plant design. The **refrigeration load** in a market milk plant consists of a high temperature load for product cooling and a low temperature load for ice making and for cooling of the refrigerator. Considerable economy is effected by designing the plant so that a portion can be operated at high suction pressure, depending on the demands of the high temperature load.

If the high temperature load is fairly steady it can be handled successfully in a system employing ammonia directly in the **product coolers** and in the **batch cooling** vats. In many plants, however, the load changes are frequent, due to variation in flow through the continuous pasteurizing equipment as a result of changes in the size of the bottles being filled, and due to the sudden demands which are made on the plant when cream and chocolate coolers or processing vats are placed on the line. These load changes are difficult to schedule accurately, with the result that the operator finds it impossible to make adjustments in capacity controls or to start and stop compressors quickly enough to follow the load. A practical solution is found by operating one or more compressors, depending on the size of the plant, automatically on suction pressure switches. In selecting automatic compressors, the load changes should be carefully analyzed and the compressors chosen to fit the average load change. Several base load compressors should run manually with the automatic compressors allowed to cut in and out as required. When automatic compressors are employed, it becomes essential to install some means of slop-over protection for the compressors.

In large plants where a number of evaporators are used some means of positive slop-over protection should be installed whether automatic compressors are used or not. Even the best of controls are sub-

ject to leakage occasionally, and a large plant should take no chances on liquid pumping with its possible damaging results.

If it is difficult to fit the capacities of automatic compressors to anticipated load changes so that the automatic machines tend to cycle, an alternative system is one using refrigerated water as the cooling medium, in spite of the attendant pumping and the double exchange of heat inherent in such a system.

Submerged coils placed in a raceway through which the water is circulated by means of an agitator are found to be very satisfactory for cooling the water used in plants of this kind. The water tank can be designed to hold enough water to absorb the increased refrigerating load during the final 35 min of the continuous pasteurizing operation, based on a rise in temperature from 33 to 36 F. This volume of water also is useful in averaging the changing rate of refrigeration which occurs when a product is cooled in a batch tank. The rate of evaporation, depending as it does on the temperature and velocity of the water in the raceway, does not change rapidly, because of the large volume in the tank, and because the ratio of water flow through the raceway to that through the product coolers is high. As a consequence, no trouble is experienced in adjusting compressor capacity to load changes.

The choice of **prime movers** for the refrigerating compressors depends entirely upon local conditions. If it is not possible to schedule the operations to secure a good load factor, and if a decided peak is found to be caused by the refrigeration load, economy can be gained by selecting a steam prime mover for one or more of the ammonia compressors. Steam at 5 lb per sq in. can be used for domestic water heating, heating and ventilating system, bottle washers, can washers and for most process operations. Considerable by-product power can be produced, only to the extent, however, that it is necessary to supply refrigeration. It is possible that the demand for refrigeration during the winter is such that only a very small part of the steam requirements can be satisfied by the exhaust. Under these conditions consideration should be given to a steam-driven generator producing power enough to bring up the quantity of exhaust steam.

In the design of a recent large plant in New York City it was determined that two daily electric peaks would occur, one at night during the proposed period of plant operation and the other in the afternoon while the batteries from the electric route vehicles were to be charged. In considering the use of a steam-driven compressor it was found that the afternoon peak could not be lowered to any great extent, since it was composed largely of a

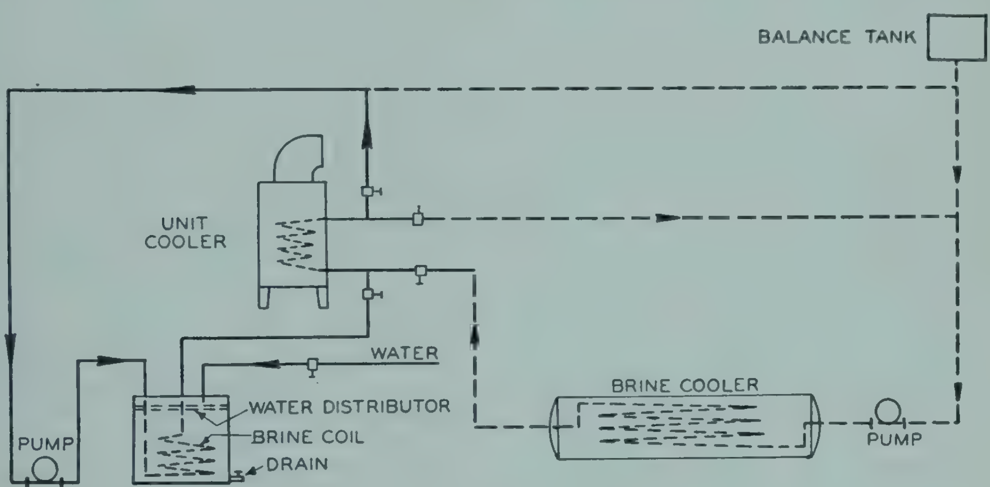

Fig. 4. Brine System for Defrosting.

battery-charging load. This was particularly true during the winter months. Since the off-peak power could be purchased at about 6 mills per kw hr, the investment in a steam prime mover could not be justified. It was therefore decided to purchase all power for the plant and to operate the boiler plant at 15 lb per sq in. pressure. The installation was designed to provide flexibility and to permit scheduling of loads in order to secure a high electric load factor. Recent operating reports from this plant indicate that during a typical summer month an average load factor of 80 percent was obtained and that the conclusions reached as a result of the prior study of the plant requirements were fully justified.

The Condensery

As in the market milk plant, milk is received in a condensery in cans directly from surrounding farmers and in tank trucks from nearby cooling stations. The problem of cooling the milk received in cans is similar to that encountered in cooling stations and market milk plants, except that it is possible to divert some of the raw milk as it is received directly to the separators. Since the separating operation is carried on at temperatures of 80 to 100 F, cooling of the diverted portion of the incoming milk is not necessary.

Evaporation is done in a vacuum pan at 130 to 140 F. The product is cooled in a jacketed tank similar to those used for batch products in a market milk plant, the initial cooling being done with cold water from springs, wells or creeks and the final cooling directly with ammonia or refrigerated water.

In designing the refrigerated water cooling system, enough water storage should be provided to prevent a rise in temperature of the stored water of more than 3 F during the beginning of the cooling period. This permits installation of a compressor based on the average requirements over the cooling period without sacrificing the advantages of rapid cooling.

The extent of cooling depends on the kind of product. Unsweetened products not sterilized are cooled to 40 F. If sugar has been added, 50 F is satisfactory since the sugar itself inhibits bacterial growth. Sterile products require no refrigeration after completion of the process, but during the operation it is usually found necessary to cool to 40 F for storage and standardizing before sterilization.

If you searched this chapter for something which was not found in it, please let the editors know.

26. BUTTER MANUFACTURE

THERE are about 3500 butter-making plants in the United States with an average annual butter output of nearly 500,000 lb each. Of this number, about 2000 make more than 200,000 lb per year each. This group includes all the large creameries and manufactures well over half of the creamery butter made in the country. In addition to 1,500,000,000 lb of creamery butter made yearly, about 300,000 lb are made on farms.

Where cream is received from the producers, a minimum of 150 to 200 Btu of refrigeration is required per pound of butter manufactured. To this must be added warehouse refrigeration, wholesale and retail refrigeration. About 130,000,000 lb of butter are held in cold storage continually for an average period of probably 120 days. Whereas butter which is held in creamery refrigerators until such time as it is shipped is generally maintained at temperatures which do not fall below 35 F, butter which is held in cold storage is maintained at a temperature of −5 to −10 F. Creameries usually hold butter for a few days only, but it may stay in cold storage more or less indefinitely.

Butter Manufacturing Process

Where butter is to be made for cold storage, special precautions are advisable. When sweet cream is used in its manufacture, precautions must be taken to grade the cream and eliminate all that is off flavor, such as "bitter," "weedy," and "metallic." Any sweet cream used in the manufacture of butter should be cooled promptly to temperatures ranging between 40 and 50 F. Even then sustained holding of such cream is likely to result in bitter flavors. Some producers have found it desirable to separate the milk while it retains the body heat and to cool the cream over a surface cooler immediately upon separation. Daily delivery is almost axiomatic for best results. Where whole milk is received by the creamery, it is separated in the plant and the cream promptly pasteurized and cooled prior to churning. If the cream is not promptly processed, there is always danger of bitter flavors developing, but since it is necessary to warm milk to approximately 90 F for efficient skimming, the recovered cream must be cooled promptly unless it is pasteurized at once. Sweet cream often develops a rancid flavor unless it is properly pasteurized.

The skim milk along with the buttermilk may then be manufactured into such products as powdered, evaporated or sweetened condensed skim milk, casein, lactic compounds, etc. Most of these products present no serious problems in refrigeration although suitable storage in cool temperatures is highly desirable.

Within recent years substantial advances have been made in the quality of butter made from cream which was sour before it left the farm. It has been amply demonstrated that prompt cooling of such cream on the farm, plus further cooling to approximately 50 F by mechanical refrigeration in receiving stations prior to delivery to the creamery, is a considerable factor in the quality enhancement of such supplies. Cooling sour cream below 50 F, however, has serious complications in bitter flavor development, as is also the case, but less marked in degree, with sweet cream. Butter made from good quality sour cream with proper consideration of its adequate processing as regards acidity adjustment, pasteurization, cooling and churning, has been found to have superior

Milton E. Parker, Author Chapter 26. Educated at Mass. Inst. of Technology, SB, 1923 Formerly, Manager of Production, Beatrice Foods Company and Dairy Technologist, Research Laboratories National Dairy Prod. Corporation.
Author, Food Plant Sanitation (McGraw-Hill, 1948).
Member, ACS; ADSA; ASME; IFT; IASM & FS; Fellow and Life Member, APHA; Member, Associates Food and Container Institute; Registered Professional Engineer, Illinois.
At present, Director, Food Engineering, and Professor of Food Engineering, Illinois Institute of Technology, Chicago, Ill. Also, Counselor in Food Production Development, Chicago, Ill.

keeping qualities both with respect to its cold storage and normal handling. Well made sour cream butter will invariably come out of cold storage with no loss of score, which is not ordinarily the case with sweet cream butter.

Butter made from sour cream invariably is subjected to precise acidity control; high pasteurizing temperatures are applied to sour cream, which is also graded rigidly. In well made sour cream butter, the cream is adjusted in acidity by the addition of harmless alkaline buffer salts so that the serum of the resulting butter has a pH value ranging between 6.4 and 7.0, the preferred range being between 6.6 and 6.8. A pH value substantially below 6.6 is likely to lead to fishy flavor storage defects in salt butter, whereas a pH value above 7.0 predisposes such butter to oxidized and even putrid off-flavors.

Incidentally, well worked butter having no substantial free moisture is a good storage risk, and a slight cooked or scorched flavor is desirable in freshly made butter prepared for cold storage, irrespective of whether it is made from sweet or sour cream.

Pasteurizing. Pasteurization may be carried out by several methods. In the "holder" method the cream may be placed in equipment which is heated by a horizontal or vertical coil through which the heating medium flows as the coil revolves in the cream, as in **Fig. 1.** In this case the cream is agitated by coils in the cream. It has been shown[1] that a pasteurizing temperature of 165 F with a 30-min holding period produces butter with the best keeping quality.

After the holding period it is essential that the cream be cooled quickly. At first cold water is used until the temperature approaches to within 10 or 15 F of that of the water. From then on "sweet" water or brine is used. It is essential that cooling through the range of temperature from 85 to 55 F be as rapid as possible in order to avoid partial churning. For this reason the rate of circulation of the cooling medium should be high and its temperature should be low. In order to economize on brine it is necessary that the coils be drained of water before turning on the brine, and that the brine be removed from the coils at the end of the cooling period. Most coils are provided with air vents to facilitate this removal. The cream is usually cooled to approximately 40 F after which it may be held for from one to several hours.

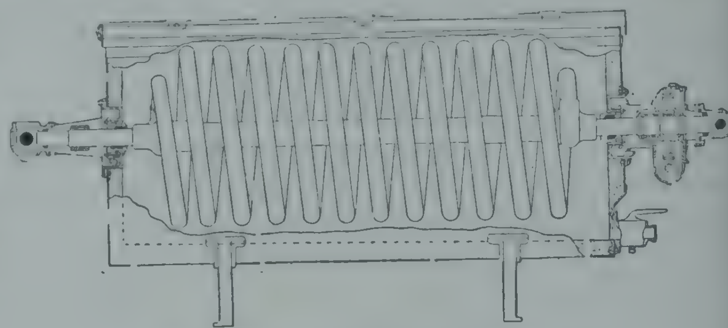

Fig. 1. Coil Vat and Holding Pasteurizer.

Some creameries, particularly the larger ones, prefer flash or **continuous pasteurization.** The present type flash pasteurizers consist of a short cylinder with an outside jacket. The inside cylinder is provided with an agitator, and steam or hot water circulates between the cylinder wall and the outer jacket. The cream to be pasteurized usually passes through the pasteurizer so that it remains in the machine for 15 to 30 seconds. The pasteurizing temperature should be at least 185 F. After it is pasteurized, cooling is generally carried out over a tubular (Baudelot type) cooler. Where ripening is practiced the temperature may be lowered to 68 to 72 F, and a ripening ferment (starter) equivalent in weight to from 1 to 5 percent of the weight of the cream may be added. After the desired acidity or flavor has been developed cooling is then continued in a coil vat.

The trend in recent years has been to higher pasteurization temperatures. A slight cooked or scorched flavor is sought in freshly made butter, as such flavors tend to disappear during holding in cold storage and furthermore have been associated with superior keeping quality. Scientific confirmation for these cooked flavors being indicative of long storage life in creamer

butter has been supplied by evidence that high pasteurizing temperatures increase the sulfhydrol production in cream subjected to temperatures in excess of 158 to 160 F, with due consideration to essential time factors. Accordingly, some modifications in flash pasteurizers have been developed in conjunction with subsequent vacuum treatments, the latter having incidental cooling and deodorizing effects which have extended the utility of cream tainted with feed or weedy flavor. These newer high temperature pasteurizers have employed temperatures of 200 to 230 F, with instantaneous cooling to 150 or 160 F in vacuum, followed by further cooling with conventional equipment to churning temperatures. In connection with high temperature pasteurizers, internal tubular coolers have been found more advantageous than open-type surface tubular coolers.

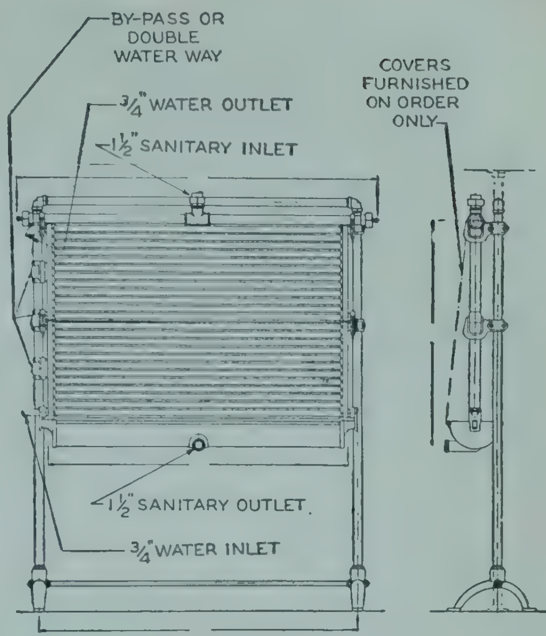

Fig. 2. Surface Cooler.

Churning. The churning temperature is so fixed that butter granules will form in approximately 45 min if the churn is not more than one-half full. The melting point of the butter fat and time the cream has been held at a low temperature have direct effects upon churning temperatures. Churning is stopped when the granules have the size and shape of popped corn. After the buttermilk has been drained off the butter is washed with an amount of water at least equivalent to the buttermilk removed. Washing is carried out by revolving the churn a few revolutions after which the wash water is drained off. The temperature of the wash water will vary with a number of conditions. Generally it is lower than the churning temperature. If trouble with crumbly bodied butter is experienced during winter months, a colder wash water is suggested for butter made from sweet cream in the northern climes. Southern butter does not always respond to such treatment. Wash water may be cooled over surface coolers or in special tanks provided with expansion coils. Whatever method is used, special care must be exercised to provide water which is as sterile as possible. In some cases, it is desirable to chlorinate the wash water to as high as 50 ppm available chlorine.

Working. The object of working is to incorporate salt and moisture and to standardize the composition of the butter. Well trained and experienced buttermakers are able to control the composition so that a fairly uniform fat content of 80.2 percent may be maintained. Formerly working was carried out in churns provided with one or more corrugated rolls. In recent years churns without rolls have been developed. Careful observations indicate that butter with as satisfactory body and texture can be produced in a "roll-less" churn as in the old models. All-metal churns of aluminum construction are at present available, although most manufacturers still use wood. Correct wash water temperatures and proper working are important for obtaining butter with a desirable body and texture.

Chilling. After the butter has been properly worked it is packed into tubs or boxes for shipping or printing. Prompt chilling is essential. Present practices call for a temperature of about 25 to 35 F. The butter will be ready for the printer after 24 hr at this temperature. It is then converted into ¼, ½ or 1-lb prints or 1 or 2-lb rolls, although some direct printing of butter as delivered from the churn is practiced. Some butter is sold directly from the tub or box in bulk, or it may be

packed in crocks. The type of printer used will determine the printing temperature. This, however, may vary between 15 and 45 F. Some of the larger creameries or butter receivers who do their own printing have provided air conditioned rooms in which to carry on printing operations.

Storage. If butter is to be placed in cold storage it is shipped from the creamery as soon as convenient after manufacturing. Some creameries wait until they have a carload, others pool shipments, and many ship by refrigerated truck. The usual type of refrigerated railroad car is used. Insulated trucks are usually equipped with a barrel of ice or ice and salt mixture to provide the necessary refrigeration. It is always good practice to chill packaged butter in a sharp freezer for 24 to 48 hr before loading in a refrigerator car especially for long hauls in warm weather.

Cold storage is at -5 to -10 F and at such temperatures it has been shown that good butter will retain its flavor and quality for a year or longer. It has also been shown that where butter was stored in parchment-lined spruce tubs, a woody flavor might be expected to penetrate approximately $\frac{1}{4}$ in. into the butter. The distance of penetration as well as the intensity of the woody flavor was as great in paraffined tubs as in the case of those not paraffined. Lining the tubs with a special moisture proof cellophane foil eliminated the defect entirely.

Studies have been made in connection with the use of various **wrappers** for the cold storage of print butter. Parchment wrappers containing .1 percent benzoate of soda, special aluminum foil, and special moisture-proof cellophane, have all been found superior to the regular grade of parchment for wrapping butter. Moisture-proof cellophane has the disadvantage, however, of not being wetted by water and therefore often imparts a smeary and unattractive appearance to the wrapper. An overwrap of cellophane with an underwrap of parchment is much to be preferred. Preliminary investigations indicate that by use of the above-mentioned special materials, print butter may be stored as satisfactorily as bulk butter in wooden tubs or boxes.

Costs. The creamery industry differs from many other branches of the food in dustry in that many of the operation must be carried out by hand labor. Wer it not for the fact that a valuable produc is being processed when butter is made, th ratio of the manufacturing cost to th total cost would be exorbitant. Plant cost usually vary between $1\frac{1}{2}$ and 3 cents per lb of butter. This indicates that at presen prices a creamery is able to return to it patrons in the neighborhood of 90 percen of its receipts. There are few industrie indeed where the margin between produce and consumer is as narrow as in the butte industry. Of the manufacturing cost abou 33.5 to 45 percent is for labor. Total fu and power costs, for example, averag .3 cent per lb of butter. The cost pasteurizing and cooling 30 percent crea by the flash method has been estimated a approximately .15 to .25 cent per lb butter, and by the vat method as approx mately one-half this amount. Power cost are particularly low since in a controlle experiment with a 300-gal coil type pa teurizer only 1.17 kw of electricity we

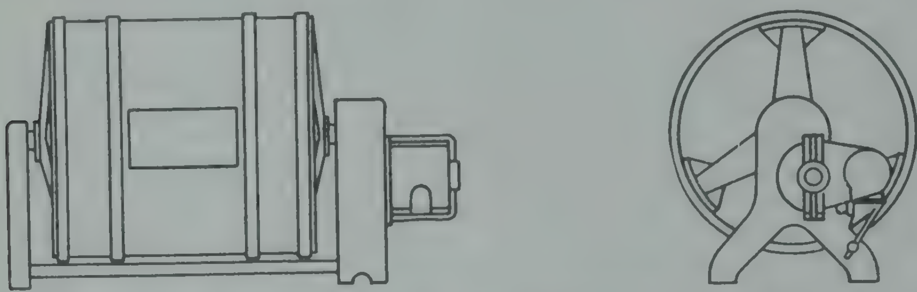

Fig. 3. Two Views of Combined Churn and Butterworker, 220 to 500 Gal.

used during 4.5 hr of operation. The churn also requires comparatively little power. For each 1000 lb of butter, a motor driven churn will probably use less than 6 kw of electricity.

Load factor. From a management standpoint it is unfortunate that most creamery operations take place during the forenoon, from about 7 a.m. to 12 noon. This means that the demand charge for electricity will very likely be high. Careful planning may help to reduce this somewhat. It is impossible to stagger the load greatly in the average creamery, since, as in all dairy plants, much of the time in the afternoon must be set aside for cleaning operations.

Refrigeration Loads and Temperatures

Practices in creamery operation are not standardized, and hence the **amount of refrigeration** per pound of butter will vary. Systems or methods of cooling likewise may be different according to the concept of the operator. **Table 1** gives elementary information on heat capacity.

Where whole milk is purchased and skimmed it may be necessary to cool the cream prior to pasteurizing it. Cooling may take place in the same equipment in which the cream is pasteurized. This machine may be a vat and is obtainable in a number of modified forms. Coils may be either horizontal or vertical. In the **coil vat, Fig. 1,** heating and cooling take place by circulating hot or cold water or brine through the coil. In the **jacket type,** the medium may be retained between an outer jacket and the inner liner. Neither type of machine lends itself to a direct expansion system of cooling. In the case of the jacket vat, there is considerable doubt if a brine system is advisable. Where it is desired to use direct expansion for cooling, either an "external" (surface) or "internal tubular" (shell type) cooler or a plate type cooler is advisable.

Three types of cooling are used, (1) the brine system, (2) the "sweet" water (chilled water) system, and (3) the direct expansion system. It may be advisable to consider a combination of any two of the above or even all three in a single plant. In a small creamery making up to 300,000 lb of butter annually, it is customary to install just one machine, and a brine system, or a combination system, although cooling pasteurized cream by direct expansion or brine over a surface cooler is inadvisable in order to avoid body and buttermilk fat loss difficulties. In other words, pasteurized cream is best cooled to approximately 85 F over a surface cooler followed by further cooling in a coil vat. Usually a 40 F refrigerator temperature is the aim, and the cream likewise is cooled to 40 F.

Table 1. Specific Heats of Some Commodities Used in the Dairy Industry

Material	Temperature, F	Specific heat
Air	68	.24
Ammonia (anhydrous)	32	.983
Brine (density 1.2, calcium chloride)	32	.71
Butter	50	.5495
Cheese (American)	50	.64
Cream (30%)	32–142	.875
Cream (30%) (frozen)	0–30	.37
Glass	50–122	.16
Ice	32	.50
Ice cream mix (12% fat)	35	.78
Ice cream (12% fat)	0	.45
Milk (3.5%)	32–142	.935
Skim milk	140–158	.963
Steel	50	.12
Water	55	1.00
Whey	73–95	.975
Wood	50	.44

Table 2 gives the relationship between brine temperature and room temperature based on practice with ammonia systems with a compressor run at a constant speed. Brine temperature will be determined by either the room temperature or cream temperature, whichever is lower. The brine temperature in turn will establish the refrigerant temperature and, therefore, the operating conditions of the compressor. (Higher temperature differences at higher temperatures are a necessary consequence of the higher density of the suction gas.)

In case a combination direct expansion and brine system is used, **Table 3** indicates that the refrigerant temperature need only be 16 F instead of 8 F in order to maintain the room at 40 F. A refrigerant temperature of 16 F when used for cooling

Table 2. Typical Relationship Between Room, Brine, and Refrigerant Temperature, F

Room temperature desired	−10	0	10	20	30	40	50	60
Brine temperature	−20	−12	−4	4	12	20	28	36
Refrigerant temperature	−28	−20	−13	−6	1	8	23	19
Temperature difference between brine and room	10	12	14	16	18	20	22	24
Temperature difference between refrigerant and brine	8	8	9	10	11	12	15	17
Temperature difference between refrigerant and room	18	20	23	26	29	32	37	41

brine might result in a brine temperature of 24 to 25 F. A minimum temperature difference of from 8 to 10 F is sufficient to bring about adequate heat transfer when brine is used for cooling cream. A brine temperature of 25 F is more than cold enough to cool cream to 40 F. Such brine, in fact, is still a reservoir for accumulating a slight amount of reserve refrigeration. The advantage of direct expansion is reflected in lower operating costs. Control is somewhat more complicated.

Where a combination direct expansion, chilled water system is used, a 16 F refrigerant temperature is amply low. Direct expansion piping at such a temperature gives the desired room temperature of 40 F in Table 3.

Chilled water from a direct expansion cooler has certain advantages, but it is important that the plant be properly engineered. A surface type tubular cooler in milk and other beverage plants may do a better job of cooling by use of chilled water. In brine or direct expansion coolers, it is not uncommon to see cream or milk frozen to the lower tubes, acting as an insulator. This freezing of the cream may injure the quality of the product. If this happens where the temperature is still too high, it is, of course, proof that too small a cooler has been provided or the cooling medium is too cold and/or circulated too rapidly. In an internal tubular cooler there is also some danger that the product being cooled may freeze in the tubes. Water coolers permit an accumulation of ice around the coils to build up a large reserve supply of refrigeration. Care and special design are necessary in applying this method, which is very useful in a creamery due to the shape of the load factor.

Water has several additional advantages over brine—that there is less danger of corrosion, and water when lost through an accidentally open valve costs nothing, in contrast to brine.

In using jacketed vats, provision must be made to eliminate pressure. This may be done by using a gravity return of the brine or water, in which case the brine storage tank must be located below the vat level, or a sump must be provided from which the brine can be pumped. A circulating pump connected directly with the vat jacket may be used, having a capacity in excess of the pump which forces the brine to the vat. An overflow or relief valve should be provided to prevent excess pressures, should the return pump fail. Diversion valves are available to bypass brine if it gets below a certain temperature.

The variety of **coils and coolers** found elsewhere is the rule also in the creamery. The ordinary expansion coil, plain or finned, is common. It is simple to install and calls for very little in the way of maintenance. The coils may be plain black, galvanized, or they may be of copper

Table 3. Typical Relationship Between Room and Refrigerant Temperature with Direct Expansion, F

Room temperature desired	−10	0	10	20	30	40	50	60
Refrigerant temperature	−15	−15	−5	3	10	16	22	26
Temperature difference	15	15	15	17	20	24	28	34

where the refrigerant is other than ammonia. Coils such as these may be located on the side wall or on the ceiling. Some installations include properly arranged baffles to provide air circulation, whereas in smaller rooms these may be dispensed with. Normally it is advisable to provide drip pans to prevent soiling of stored butter. The unit cooler with fan has become popular. Many coolers of this type do not operate satisfactorily at room temperatures below 35 F due to difficulty of defrosting.

Continuous Buttermaking Process[7]

The butter industry throughout the world has been studying ways to improve the manufacture of butter. Some of the more prominent developments for making butter continuously include:

1. The Senn method from Switzerland.
2. The Alfa continuous buttermaking process. Germany.
3. The Fritz continuous buttermaking process. Germany.
4. The New Way continuous buttermaking process. Australia and New Zealand.
5. The Creamery Package continuous buttermaking process. U.S.A.
6. The Cherry-Burrell continuous buttermaking process. U.S.A.

The patent files of various countries show much additional study being given; however, the extent of field tests and success is unknown. This discussion will deal only with the Cherry-Burrell continuous butter process because at the present time it appears to be the most important one commercially. This does not mean that other methods do not have commercial value. The Cherry-Burrell process is merely illustrative and is offered to apprize the reader of progress in this field. No attempts to make comparisons with other processes will be made.

The Cherry-Burrell continuous buttermaking process is the result of a joint research undertaking in which the Cherry-Burrell Corporation was invited to cooperate in a study undertaken by the Sugar Creek Creamery Company of Danville, Illinois. This study began in 1940 and resulted in the first commercial installation at the Sugar Creek Creamery, Danville, Illinois, October 1948, of a double unit which has a top capacity of 4,000 pounds

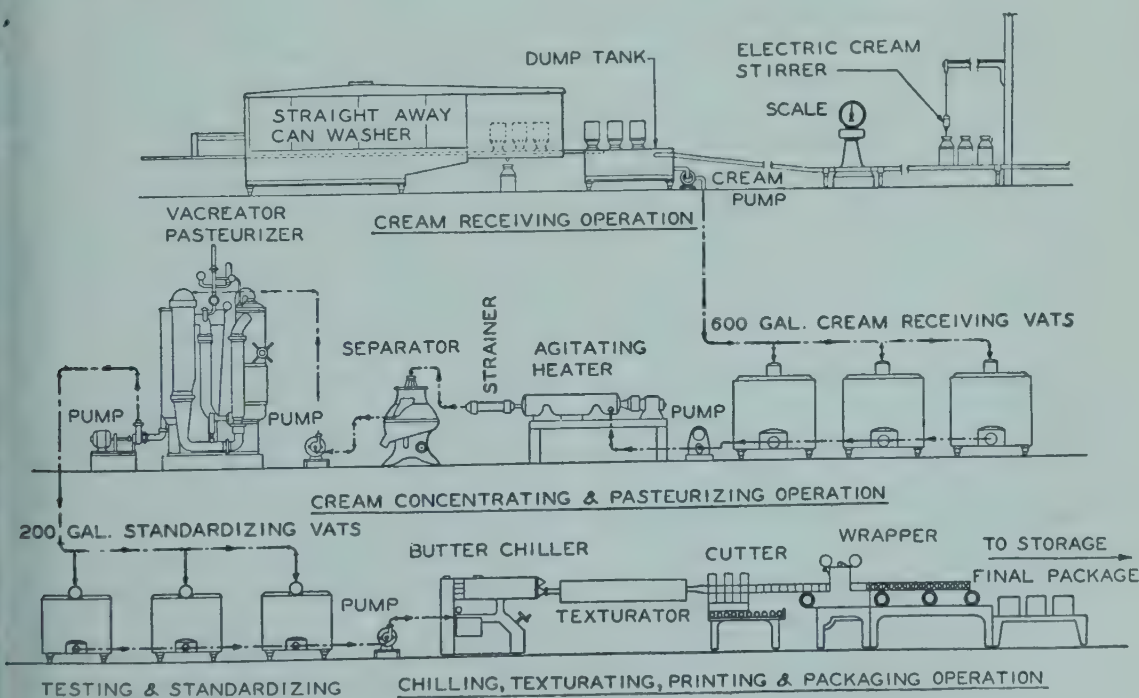

Fig. 4. Continuous Buttermaking-Flow Diagram. 2000 lb per hr Capacity.

of butter per hour. Previous to the installation of commercial equipment, experimental equipment was used. However, it should be mentioned that during the first eight years the experimental runs were made on equipment of commercial size which had a variable capacity between 1,000 pounds and 2,000 pounds of butter per hour. In this development work no attempt was made to produce a single unit machine that would make butter continuously, nor was any attempt made to have all of the process continuous. The object of this study was to develop a process of making butter which would be superior to the batch churn method of making butter.

Butter from both sweet and sour cream has been produced with this process. However, a large part of the study has been made with sour cream since the greater part of butter made in the United States is from sour cream.

General outline of process

Briefly the process consists of heating the cream to 120 F, separating to above 88 percent fat, pasteurizing this concentrate, and standardizing it in batches to 80 percent fat. The standardized mixture is then chilled to solidify most of the fat, followed by working to impart spreadability.

Heating before separation. The cream which contains between 30 and 40 percent fat is heated in a centrifugal heater from the receiving temperature between 45 to 60 F to 120 F. The centrifugal heater handles cream at about 5,000 pounds per hour, which is sufficient to produce 2,000 pounds of butter per hour if the fat content is 32 percent or over. The centrifugal heater is used to heat the cream (1) to the temperature most efficient for separating, (2) to agitate and break lumps of curd and liberate the fat in the lumps and (3) weaken the emulsion of the cream so that the separator can break the fat emulsion and separate to a higher concentration of fat.

Samples of cream from the centrifugal heater at 120 F show no signs of fat separating and rising, although some destabilization of the fat emulsion is apparent under the microscope.

The centrifugal heater consists of a vertical steam jacketed cylinder about 15 inches in diameter and 32 inches high. Cream enters the bottom and is forced upward through the heater by the lifting action of the agitator. Blades similar to those in a centrifugal pump on top of the agitating member force the warm cream from the heater. It has been found that it is not necessary to scrape the heating cylinder with agitator blades when the agitator operates at 375 rpm. The agitating blades clear the jacket by about $\frac{1}{2}$ inch.

When operation of the heater is examined with a stroboscope the cream appears as a layer between the heating cylinder and the agitator, and the remainder of the heater is empty.

Separation. The separator used in this work is an American DeLaval industrial separator with a capacity of about 5,500 pounds of cream per hour. There are three discharge ports from the separator, one for the concentrated milk fat, one for skim which we shall term "light skim," and one for "heavy skim" or skim which contains additional curd and other heavy entrained solids which may be in the cream. The discharge of the heavy skim is accomplished by means of three ports or valves in the periphery of the bowl. These valves open and close automatically, depending on the amount of heavy skim they contain. The discharges from the skim milk and cream ports are so balanced that when there is little or no fat in the product there is little or no discharge from the fat outlet, so regardless of the composition of the product being separated, fat is never discharged from the skim milk port, and skim milk is never discharged from the fat port.

Early in the work it was noted that neutralization of the cream acid produced a physical modification of the curd which resulted in clogging of the bowl after a short period of operation. Sodium carbonates and sodium hydroxide produced a rubbery curd while calcium and magnesium hydrate produced a dry curd. Each effect prevented elimination of the curd through the heavy skim ports.

Heating the cream above 120 F also has been found to reduce skimming ef-

ficiency largely by increasing the fat loss in the heavy skim.

Table 4 shows the analysis of fat in the fat concentrate and in both the light and heavy skim milk. It also shows the pounds and percentage of fat lost in the various fractions and the total fat lost. The figures in this table represent what is considered good operation, and are not given to show maximum variations which might occur. Considerably lower as well as considerably higher fat losses have been experienced during the years of trial operation. However, high extremes have been progressively reduced by separator changes. Note that the greatest amount of fat lost in the sour cream is lost in the heavy skim milk fraction. Some of this fat is mechanically locked in curd lumps. The orifices in the heavy skim milk valve range between 0.025 and 0.032 inch, and in order to keep them from clogging it is necessary that the solid particles above this size be removed previous to separation. The warm cream is, therefore, passed through a stainless steel filter having 0.020 inch holes in it. When the cream is so filtered the separator can operate for eight hours or longer without clogging.

The curd deposits to a maximum thickness in the bowl during the first fifteen minutes of operation. At the end of an eight-hour run there is little if any increase in the thickness of the curd deposit. The deposit in the periphery of the bowl is thickest (about one inch between the orifices), tapering to nothing at the heavy skim milk orifices.

Pasteurization. The concentrated fat is pasteurized directly after separating. The fat concentrate passes through a balance tank where alkali may be added if desired to neutralize excess acid. A calcium and magnesium hydrate mixture has been preferred to sodium carbonates or sodium hydroxide and is added to standardize roughly when sour cream is used. The fat concentrate is pasteurized continuously in a "Vacreator" or vacuum pasteurizer. In the vacuum pastuerizer the product is heated in the first chamber to 200 F where pasteurization is accomplished in less than a second. It passes from the pasteurizing chamber to a second chamber

Table 4. Record of Operations Separating 36.5% Cream, 0.70% Acidity

Trial number	Fat concentrate			Light skim milk			Heavy skim milk			Separator capacity pounds per hour	Pounds of fat processed	Total pounds of fat lost	% Total of fat lost	Proportion of lost fat in the	
	Pounds per hour	% Fat	Pounds of fat	Pounds per hour	% Fat	Pounds of fat	Pounds per hour	% Fat	Pounds of fat					Heavy skim	Light skim
1	2054	87.7	1801	2340	0.20	4.6	522	2.0	10.4	4916	1816	15.0	0.87	69.9	30.1
2	1890	87.5	1653	2354	0.16	3.7	526	2.2	11.4	4770	1668	15.1	0.90	75.5	24.5
3	2280	83.4	1801	2100	0.30	6.3	562	1.6	8.9	4942	1816	15.2	0.83	58.5	41.5
4	2040	82.7	1687	2160	0.18	3.8	490	1.8	8.8	4690	1700	12.6	0.74	70.0	30.0
5	1860	89.4	1662	2280	0.28	6.3	472	1.8	8.4	4612	1677	14.7	0.87	57.0	43.0
6	1934	88.7	1715	2354	0.28	6.5	547	2.0	10.9	4835	1732	17.4	1.00	62.5	37.5
7	1920	89.0	1708	2280	0.20	4.5	510	1.6	8.1	4710	1721	12.6	0.73	64.5	35.5
8	1980	89.2	1766	2234	0.20	4.4	525	1.6	8.8	4739	1779	13.2	0.74	66.6	33.4
9	1950	91.3	1780	2280	0.24	5.4	585	.96	5.6	4907	1791	11.0	0.61	50.9	49.1

maintained at about 17 inches of vacuum with a temperature of about 170 F. Here the product is subjected to the effect of the vacuum treatment and to steam distillation. The mixture then passes through the third chamber maintained at a vacuum between 27 and 27.5 inches where it is cooled to approximately 110 F. The product leaves the Vacreator at or near the temperature it entered and has practically the same composition.

Table 5. Composition of Butter Made by the Cherry-Burrell Continuous Butter Process

Test No.	1	2	3	4	5
Moisture, %	16.3	17.1	16.4	16.7	16.8
Fat, %	80.0	80.0	80.3	80.3	80.2
Salt, %	2.6	2.3	2.5	2.5	2.3
Curd, %	1.1	.6	.8	.5	.6
pH of Serum	7.0	7.04	6.94	6.88	7.34

Standardization. The concentrated fat is accumulated in the standardizing vats where it is analyzed for acidity, moisture, and curd, and then standardized to the desired 80 or 80.2 percent fat. The acidity is reduced to a pH of 6.8 to 7.0.

The problem of keeping the moisture and fat uniformly distributed in a 200-gallon vat for testing and standardizing, and later operations, has not been simple. The basic problem is that of attaining and maintaining uniform composition of a 200-gallon tank of an oil and brine mixture. By means of agitators and baffles, a vertical-rotational direction of the product has been produced and the brine in the mixture distributed uniformly throughout the mass. Representative compositions of the butter are shown in Table 5.

In this table covering a two-year period the curd content of the continuously made butter varied from 1.1 percent and 0.5 percent. The average is somewhat lower than batch churned butter. Higher curd content can be obtained by standardizing with butter culture instead of water. No objections to using pasteurized skim milk or butter culture have been found.

The standardized mixture is held at 105 F to 110 F and it is important that crystallization of fat be avoided in the standardizing vat. When the temperatures are as low as 95 F and remain there for a substantial period of time, mealy butter has resulted due to the growth of large crystals of fat. Standardizing vats are, therefore, equipped with means of maintaining temperatures between 105 F and 110 F. The amount of fat concentrate in the 200-gallon standardizing vat is determined by means of a calibrated measuring rod. Fat, moisture, and acidity are determined and the proper amount of salt, water, neutralizer, and flavor are mixed together and added to the vat.

Chiller worker. The chiller worker consists of two horizontal jacketed chilling tubes, each 6 inches in diameter and 42 inches long. The tubes are equipped with scraper blades and means for working the butter, and are ammonia cooled. The chiller is usually operated at about 18 pounds suction pressure. At the rated capacity of 2,000 pounds per hour, approximately 11 tons of refrigeration are required based on the assumption that milk fat has a specific heat of 0.475, the serum 0.85, and that the heat of fusion of milk fat at 40 F is 33.3 Btu per pound. It is always desirable to have an extra ton or two of refrigeration as all systems have some oil in them which tends to increase refrigeration requirements.

Chilling and partial working of the butter is accomplished simultaneously as it is pumped through the chiller. The agitators which work the butter also have scrapers which remove the chilled butter from the cylinder wall. In the first chamber the product is chilled from 110 F to approximately 50 F, and in the second chamber to approximately 40 F. The discharge temperature varies between 38 F and 43 F depending on the properties of the fat. To maintain uniform spreadability, the chilling temperature is raised as harder fat is chilled. A butter sample taken from the first cylinder at 50 F becomes very hard and brittle in about one minute and maintains these characteristics unless it is worked in some mechanical way. After the butter is allowed to go through the second chamber where it is worked further as it is cooled and where additional crystallization takes place, it is somewhat less hard and

brittle but the butter is still too hard for acceptable spreadability.

When the butter is permitted to remain substantially quiescent for three or four minutes and then worked or kneaded gently, it becomes waxy and pliable; it coheres to produce a close-bodied, fine textured product, which after a few hours of storage becomes plastic and spreadable.

Texturator. The working or kneading required after the butter leaves the chiller worker is accomplished by passing the butter through a texturator. The texturator consists of a cylinder 9 inches in diameter with funnel shaped connections on either end. The butter is discharged from the chiller through a $1\frac{1}{2}$ inch connection, and then passes through a cone about 14 inches in length in which the diameters go from $3\frac{1}{2}$ inches to 9 inches. It passes through 36 to 42 inches of 9-inch tubing after which a second cone reduces the butter passage from 9 inches to $3\frac{1}{2}$ inches, or whatever sized extrusion of butter is desired. The passage through the second cone works the butter sufficiently to give it the desired properties for good spreadability.

As the butter passes through the texturator, crystallization of the fat continues as indicated by a rise in temperature of 2 to 3°. A further rise in temperature continues for 15 to 20 minutes, indicating that some additional crystallization is taking place. During this 15 to 20 minutes the butter becomes somewhat firmer. The body, texture, and spreadability can be modified by changing the chilling temperature, the texturator length, and the location and number of cones.

A means of adding a small amount of nitrogen is provided on the chiller. Churned butter generally has 4 to 5 percent dissolved and entrained air. A meter similar to those used in administering oxygen in hospitals is used for controlling the quantity of gas added. It registers the milliliters of gas delivered per minute. Approximately 700 ml of nitrogen are added per minute when operating at 2,000 pounds of butter per hour.

Properties of the butter

In general the butter may be described as a close-textured, fine bodied product possessing the properties of well made, well worked churn-made butter. Comparisons of the samples of the Cherry-Burrell process butter with churn-made butter would bring out some differences. The continuously-made butter would have closer texture and finer body than the churn-made product.

For equal quantities of salt, diacetyl or color added, butter made by the Cherry-Burrell process shows slightly less effect than does butter made by the churn process; the flavor is more bland and the color is lighter. The keeping quality of the Cherry-Burrell butter as indicated by the seven-day test at 70 F is superior to that of the churn-made product.

Considerable interest has been manifested in the difference in crystalline structure of butter made by the two processes. One observation of some interest is that the crystals in churn-made butter change considerably the first few days after manufacture. Well chilled churn-made butter has considerable resemblance to Cherry-Burrell made butter in crystalline structure. Detailed studies on this subject have as yet not been made.

Butter in good firm condition may be packaged an hour after the process is started. The equipment is easy to operate; some skill and proficiency are required to test and standardize the fat concentrate to insure uniformly correct composition of the final product.

The principal advantages expected of the Cherry-Burrell system over churn-made butter may be listed as follows:

1. Improved sanitary conditions of manufacture through the elimination of the wood churn.
2. Elimination of the buttermilk early in the process.
3. Reduction of the lapsed time from receiving the cream to the delivery of the packaged product.
4. Composition control improved in that the composition of the butter is known before the final operation is started.
5. Better control of body texture and spreadability and close uniformity is obtained as all butter receives identical treatment.

6. Leakiness of butter is eliminated.
7. Uniform distribution of water and salt in minute brine droplets.
8. Reduction of space occupied by the processing equipment.
9. Slight reduction in the cost of manufacture per pound of butter.
10. Reduction of labor.

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27. CHEESE MANUFACTURE

THE great bulk of the cheese produced in the United States is American or cheddar type cheese. The physical shape of cheddar type cheese varies from the 80-lb block to the 12-lb longhorn and, more recently, the 1, 2, 5, and 10-lb loaves and the 40-lb block. However, the great majority of cheddar type cheese is in the form of the familiar 70-lb cheddars, 35-lb twins or 20-lb daisies. As a result of the modifications of sizes, storage of cheese is somewhat complicated from a standpoint of space requirement. With the exception of the 80 and 40-lb block and the 1, 2, 5, and 10-lb loaves, all other cheese forms are cylindrical in shape and hence require materially more space. The advent of the 40-lb block may materially change the refrigeration and space requirements for cheese storage. Packaged in cube form and overwrapped in a sheet of film having a low moisture-vapor transmission, this style of cheese reduces to a minimum humidity control and space requirements.

Current cheese is rubbery in texture and has little flavor. Perhaps the most characteristic flavor of current cheese is a clean, slight, acid flavor. The presence of pronounced flavors in current cheese indicates a poor quality cheese. Upon curing under proper conditions, however, the body of the cheese will break down, and a nut-like full-bodied flavor will develop that is characteristic of aged cheese. These changes are accompanied by certain chemical and physical changes during the curing process. The calcium paracaseinate of cheese gradually changes into monoparacaseinate, proteoses, amino acids, and ammonia. These changes are a part of the cheese ripening process and may be controlled by temperature of storage.

The **bacterial flora** of cheese play an important role in the development of aged flavor and body characteristics. Formerly most cheese was made from raw milk. Recently, however, the pasteurization of milk for cheese making has become generally adopted throughout the industry. Raw milk cheese contains not only the lactic acid producing organisms such as S-lactis which are added to the milk during the cheese making process, but also the heterogeneous mixture of microorganisms present in the raw milk many of which frequently produce gas and off-flavors in the cheese. With the advent of pasteurization of the milk, some degree of control of the bacterial flora of the cheese is now possible.

As the cheese ages, bacteria development produces the cheese changes characteristic of their strain. It is impossible to determine in an unripened cheese what bacteria are present and what changes are to be anticipated. The best index, and one which has been accepted, is the scoring procedure for cheese. Cheese is scored on a basis of body, texture, flavor, aroma, and color. The body, texture, flavor and aroma of the cheese are, in a sense, an index of the bacterial flora and character of the milk used in the manufacture of the cheese. They are further an indication of the technique of the cheese maker. However, it has been the experience of the industry that a current fancy, or No. 1, cheese may upon age, even under ideal conditions, become an undergrade cheese. It is because of this fact that the **aging** of cheese has become a specialized industry.

Although the tendency today is toward

R. J. REMALEY, Author Chapter 27. Born 7/24/10, in McKeesport, Pennsylvania. Educated at Univ. of Pittsburgh. Formerly, Chief, Dairy Products Branch, Quartermaster Subsistence Research Laboratory.

Member, Amer. Dairy Science Assn.; Inst. of Food Technologists; Amer. Assn. for the Advancement of Science; Intl. Assn. Milk and Food Sanitarians; Advisory Council, Illinois Inst. of Technology; Activities Committee, Associates, Food and Container Institute.

Author, "Fat Problems in Dairy Products," *Natl. Butter and Cheese Journal*, 3/46; "Concentrated and Dry Ice Cream Mixes," *Southern Dairy Products Journal*, 2/48; "Dry Milkfat as a Form of Storage Fat in the Dairy Industry," *Milk Plant Monthly*, 3/48; Chapter 25, 1946 Applns. Vol., ASRE Data Books.

At present, Manager Research Administration, Kraft Foods Company, Glenview, Illinois.

larger cheese factories, the bulk of cheddar cheese is produced in small cheese plants—that is, plants having a capacity of about 20,000 lb of milk per day. Such cheese plants will average somewhere in the neighborhood of 10,000 lb of milk a day. These cheese plants have little, if any, facilities for proper aging of cheese. Consequently, most cheese is shipped to centralized storage plants for curing. In larger plants, however, where proper facilities are available, the cheddars, immediately after removal from the press, are placed in cold storage at from 32 to 34 F and held at this temperature for approximately 30 days before being placed in cure. Holding the cheese at this temperature for at least a month is almost an essential part of proper curing. During this period of time the curd particles knit together forming a close-bodied cheese, and the calcium paracaseinate is largely converted to calcium monoparacaseinate. In short, the most critical stage of cheese curing is during this 30-day period.

Unfortunately, the great bulk of cheddar cheese manufactured in this country, because of the lack of facilities of the cheese plant, is not stored under these ideal conditions during this time. Generally, cheese from a small plant will be held 10 to 14 days at temperatures ranging as high as 50 F and then shipped to a centralized curing plant either in cars or trucks, and hence is subject to temperatures even as high as 70 to 80 F. When this cheese arrives at the centralized plant, in order to stop further bacterial growth, it is a good practice to place it in the cool room at 32 to 34 F and hold it there for approximately two weeks before curing. However, in many instances these centralized plants do not have facilities for holding cheese at these low temperatures and the cheese is immediately placed in cure at 38 to 42 F.

Curing Cheddar Cheese

Cheddar cheese contains approximately 37 percent moisture, 63 percent solids. The specific heat of cheese is 0.65. Proper curing of cheese requires that cheese be heated throughout to a constant temperature and held at such constant temperature

Table 1. Curing Temperatures for Cheddar Cheese

Temperature, F	Relative humidity, %	Length of time for cure
32–34	70	12–18 months
38–40	70	8–10 months
45–55	85–90	60 days
55–70	85–90	Indeterminate

during its curing period. A period of 7 to 1[illegible] days is generally required to raise the tem perature of the cheese to the curing tem perature.

Table 1 shows the curing cycles fo cheddar cheese to obtain approximatel the same flavor and body development. I should be pointed out that the flavor produced at all four temperatures are char acteristic of the curing temperature—tha is, a cheese cured at 45 to 55 F. for 6 days, will have the same approximat flavor as a cheese cured at 32 to 34 F fo 12 to 18 months, but with definite and dis tinct overtones which are characteristic forced curing or cold storage curing. Tabl 1 is based upon initially holding the chees immediately after manufacture at 32 for a period of 30 days prior to placing i cure. The time indicated does not incluc this 30-day holding period.

Holding of cheese for cure under an circumstances should be limited to fancie no. 1's or no. 2's. An expert cheese grad should be on hand at all curing rooms plug the cheese constantly to determine th development of the cure. Cheese for curin purposes should be "tailor-made." Chee of high moisture will develop off-flavors curing more rapidly than cheese of lo moisture. Cheese having loose or crumb bodies, or having high acidity, will not cu out properly. For best curing, chee should not contain more than 37 percen moisture and preferably less. The stora at curing temperature of standard mark cheese, which has not been specifically pr duced for curing, results in extremely hig losses. **Table 2** is an estimation of the loss which may be anticipated.

The losses indicated in Table 2 may controlled by continually plugging an checking the cheese. Experience in indu

Table 2. Estimated Losses of Market Cheese when Stored without Proper Controls[1]

Temperature, F	Time, mo	Percentage of loss Fancies	No. 1's	No. 2's
32–34	12–18	10	10	10
38–40	8–10	10	10	30–40
45–54	2	20–30	30–40	40–50
55–70	2	30–40	40–50	50–60
Over 70	2	In excess of 60 in all grades.		

[1] National Cheese Institute, Research Committee.

try has been that, provided the cheese is plugged within 10 days after going into cure and then approximately monthly thereafter, those lots of cheese which indicate poor curing characteristics being culled, the maximum loss experienced when cured at temperatures under 55 F will be approximately 5 percent. The culled cheese is not lost but is placed on the market and sold as a semicured product.

Moisture Losses of Cheddar Cheese

The loss in weight of cheese during cure is largely attributed to moisture loss. Paraffined cheddar cheese going into cure will average approximately 37 percent moisture. After a 12-month cure at 40 F paraffined cheese will average approximately 33 percent moisture. This loss in weight is a real loss to the cheese manufacturer unless the cheese is sold for processing. In that event the cheese is bought on a fat and total solids basis at no loss.

Table 3. Summary Curing and Storage of Cheddar Cheese

Type of cure	Temp F	Relative humidity, %	Ideal temperature of storage after cure, F	Maximum temperature range of storage, F
Cold storage	32–34	70	30–34	32–60
Standard	38–40	70	30–34	32–60
Force cure (on shelves)	45–55	85–90	30–34	32–60
Force cure (in boxes)	45–55	75–80	30–34	32–60

Control of humidity plays an important role in reducing this loss in cheese curing. Fig. 1 shows the moisture loss of paraffined longhorns in boxes held at 38 F, 70 percent relative humidity, over a 12-month period. This study was made under carefully controlled conditions and shows an average loss of 7 percent. It should be pointed out that the high moisture loss shown in the graph can be accounted for by the larger amount of surface area exposed in the 12-lb longhorn as opposed to the 35-lb twin or 70-lb cheddar. Controlled experiments reported by Van Slyke and Price[1] show that cheese held at 60 F, rh 75 to 80 percent, will lose as much as

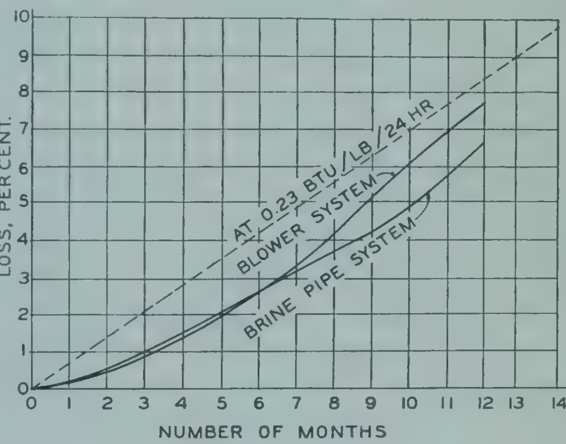


Fig. 1. Shrinkage of Cheese in Storage.

9.69 percent moisture during the 12 months' storage, whereas when held in an atmosphere completely saturated with moisture during the same period of time at the same temperature, cheese actually gained 1.7 percent moisture. The same investigators also reported that as the moisture of the cheese increased from 35 to 55 percent, the loss in moisture of cheese when held for 4 weeks varied from 5.7 percent at a 35 percent moisture level to 16.8 percent at a 55 percent moisture level.

Many attempts have been made to overcome this moisture loss. One of the most satisfactory has been that of paraffining cheese. The use of paraffine will reduce the moisture loss of cheese about 75 percent. The curing of cheese within a

[1] Van Slyke, L. L. and Price, W. V., *Cheese*, pp 274–280.

sealed wrapper having low moisture-vapor, and oxygen and some carbon dioxide transmission largely eliminates loss from moisture.

Table 3 summarizes the various temperatures of cure and storage for cheddar cheese.

Washed Curd and Colby Cheese

Washed curd and Colby type cheeses are modifications of cheddar cheese. Aside from slight modifications in the method of make, the moisture of Colby cheese may be as high as 40 percent, and the moisture of washed curd as high as 42 percent. These higher moisture cheeses are generally cured at the temperature range of 38–40 F, with a relative humidity of approximately 70 percent. Most of these types of cheese are placed on cure immediately after make and are marketed every 30 days. However, Colby cheese, and occasionally washed curd cheese are sometimes held in cure for as long as six months. Whenever it is anticipated to cure either of these types of cheese for any period greater than 30 days, it is a good practice to hold these cheeses at 32 to 34 F immediately after make for at least 30 days before placing them in cure at the 38 to 40 range. Both washed curd and Colby type cheese are more subject to development of off-flavors and gas than standard cheddar type cheese. All curing of these types of cheese must be carefully controlled.

Swiss Cheese

A considerable amount of Swiss cheese is produced in the United States. Swiss cheese requires careful temperature control during the make as well as in the final curing process. Table 4 shows the common temperatures used during the Swiss cheese make and cure.

The control of temperature and humidity during Swiss cheese curing are of the utmost importance for the proper development of flavor. Too high a relative humidity will cause excessive mold growth and too low a relative humidity will cause cracks in the rind. The temperatures and relative humidities reported in Table 4 are representative and are frequently varied by the individual manufacturer.

Roquefort or Blue Cheese

Common temperatures which are used in America for the making and curing of blue or Roquefort type cheese are contained in Table 5.

Fig. 2. Redskin Curing Room—Pabstett Corporation, Plymouth, Wisconsin.

For years it was believed that the development of flavor of Roquefort cheese was due to a particular type of mold or condition found in the caves in the village of Roquefort, France. However, it has been learned fairly recently that proper control of mold culture and of the temperature and humidity will produce as good a quality blue cheese as the imported

Table 4. Temperature of Swiss Cheese Make and Cure

Part of process	Temperature, F	Relative humidity, %	Time, days
Salting room	50–54	In brine	4–6
Cool room	40–45	70	10–14
Warm room	68–77	80–85	14
Curing room	60	80–85	14–28
Holding room	35–40	70	120–360

Table 5. Temperature of Blue Cheese Make and Cure

Part of process	Temperature, F	Relative humidity, %	Time, days
Form room	68–72	80–90	3–5
Curing room	48–50	95	90
Holding room	40–45	70	90–180

Table 6. Curing Temperature of Other Common Varieties of Cheese

Type of cheese	Temperature of cure, F	Relative humidity, %	Time of cure, days
Brick	60–65	90	60
Limburger	60–65	95	42
Camembert	53–59	90	21
Cream Cottage Neufchatel	No Cure		

product. In the same instance, even in the United States, caves are used for curing. The most extensive use of caves in the United States is around St. Paul, Minnesota, where the temperature and relative humidity are constant the year round without the use of special refrigeration equipment.

Other Cheeses

Table 6 shows the approximate temperatures and relative humidities used for curing various other types of cheese which are common in America.

Freezing of cheese may break the natural emulsion in the cheese. If cheese is frozen and permitted to thaw gradually, very little change will be noticed in the product. However, it is inadvisable to subject cheese to freezing temperatures.

Table 7 shows the freezing points of common varieties of cheese as determined by Watson and Leighton, Bureau of Dairy Industry, United States Department of Agriculture.

The oiling-off point of all types of cheese except process cheese is about 68 F. When cheese is held above its oiling-off point the fat will leak from the body and will rapidly develop rancidity. Cheese should never be

Table 7. Freezing Points of Various Cheeses

Type of cheese	Freezing point, F
Brick	16.3
Cheddar	8.8
Cottage	29.8
Limburger	18.7
Process (American)	16.6
Process (Swiss)	17.5
Roquefort	3.7
Swiss, domestic	14.0
Swiss, imported	14.7

Watson, P. D., and Leighton, A., *Jour. of Dairy Science*, vol. 10, p. 332.

Table 8. Temperature Range of Storage, Common Types of Cheese

Type of cheese	Ideal temperature of storage (for longest shelf-life), F	Maximum temperature range of storage, F
Brick	30–34	16.3–50
Camembert	30–34	20 –50
Cheddar	30–34	8.8–60
Cottage	32–34	32 –50
Cream	32–34	32 –50
Limburger	30–34	18.7–50
Neufchatel	32–34	32 –50
Process American	50–70	20 –100
Process brick	40–60	20 –80
Process limburger	40–60	20 –80
Process Swiss	50–70	20 –100
Roquefort	30–34	3.7–50
Swiss	30–34	14 –60
Cheese foods	40–60	20 –70

held at temperatures in excess of its oiling-off point.

Processing cheese protects the cheese from oiling off. By heating the bulk cheese to temperatures of 140 to 180 F, and through the incorporation of emulsifying salts, a more stable emulsion is formed than in the natural or non-processed cheese. Process cheese will not oil off even at melting temperatures. Because of the temperatures used in processing, process cheese is essentially a pasteurized product. Microorganisms causing changes in the body and flavor of the cheese during cure are largely destroyed, hence there will be practically no further flavor development. Consequently, the range of temperature for the storage of process cheese is considerably broader than any of the other types. **Table 8** shows the maximum temperatures of storage for cheese of various types for limited lengths of time.

If you searched this chapter for something which was not found in it, please let the editors know.

28. BAKERY REFRIGERATION

REGARDLESS of the size and kind of bakery, temperature control is necessary for the production of high quality products on a rigid production schedule. Temperature control enters with respect to the flour and other ingredients, the cake mix or the bread dough mix, the fermentation process, the proof box, the oven, the bread cooling and the refrigerator.

The control of any temperature below normal requires refrigeration, the amount depending on the products and conditions desired. In selecting such equipment several related factors have to be taken into consideration, such as present production and future expansion, climatic conditions, building construction and desired uses, permissible investment and the like.

Refrigeration enters the process in at least the following points in production:

1. Storage
   a. Flour, cool storage in summer
   b. Other ingredients, such as yeast, butter, milk, shortenings, eggs
   c. Frozen ingredient storage
   d. Finished products containing cream, custard, etc.
2. Water cooling—process water
3. Cooling in process
   a. Mixer cooling
   b. Fermentation room
   c. Bread cooling
   d. Retarding doughs and batters
   e. Cold slabs and special processes
4. General air conditioning.

WILLIAM H. CATHCART, Author Chapter 28. Educated at Indiana University, AB, 1933; Indiana University, AM, 1934; New York University, PhD, 1936. Formerly, Director of Laboratory at American Institute of Baking, 1936–41.

Co-author, "Freezing as a Means of Retarding Bread Staling," *Ind. Eng. Chem.*, 1939; "Further Studies on the Retardation of the Staling of Bread by Freezing," *Cereal Chemistry*, 1941; "Defrosting Frozen Foods by High-Frequency Heat," *Food Research*, 1946; "Freezing Preservation and the Baking Industry," *Western Canner and Packer*, 1947; author, Chap. 26, 1946 Applications Vol. ASRE Data Books.

Member, Amer. Assn. for Advancement of Science; Amer. Chemical Society; Amer. Assn. of Cereal Chemists; Inst. of Food Technologists; N.Y. Academy of Sciences; Society of Amer. Bacteriologists.

At present, Director, Laboratory of National Bakery Division, the Great Atlantic and Pacific Tea Co., New York City.

The Baking Process

In making a typical white bread, flour is mixed with water in the approximate proportion of 100 to 60 with the addition of yeast, sugar, dry milk, shortening, salt, mineral salts and malt extract, which ingredients together compose on the average about 20 percent of the mix by weight. For raisin and other special breads more elaborate formulas are involved. **Fig. 1** indicates the fundamental operations involved.

One type of sifter is a device consisting of a cylinder with a hopper through which the flour enters a spiral brush for agitation before passing one or more sieves. Vibrating sifters are also practical. Here lumps and foreign substances are removed. The sifter may be combined with a blender if several varieties of flour are used. In the next operation, mixing, the flour arrives in a weight hopper by means of a conveyor. Water is supplied by a weighing device, equipped with a thermometer. The other ingredients are added, and the mixing takes place by means of a set of motor-driven steel arms which give the resulting dough a mixing, pounding and stretching effect. This process develops the gluten content of the flour, to which the strength of the dough is to some extent proportional. The time required varies with the strength of the flour.

Two kinds of dough may be identified, the first being **straight dough,** in which all ingredients are mixed at one time, requiring from 10 to 20 min in the mixer. The other variety is known as **sponge dough.** In the latter, mixing takes place in two stages with a period of 3 to 5 hr between, in which the sponge (first mixture) is allowed to rise in the fermentation room. Fermentation takes several hours in either case.

After the dough is fermented it is taken

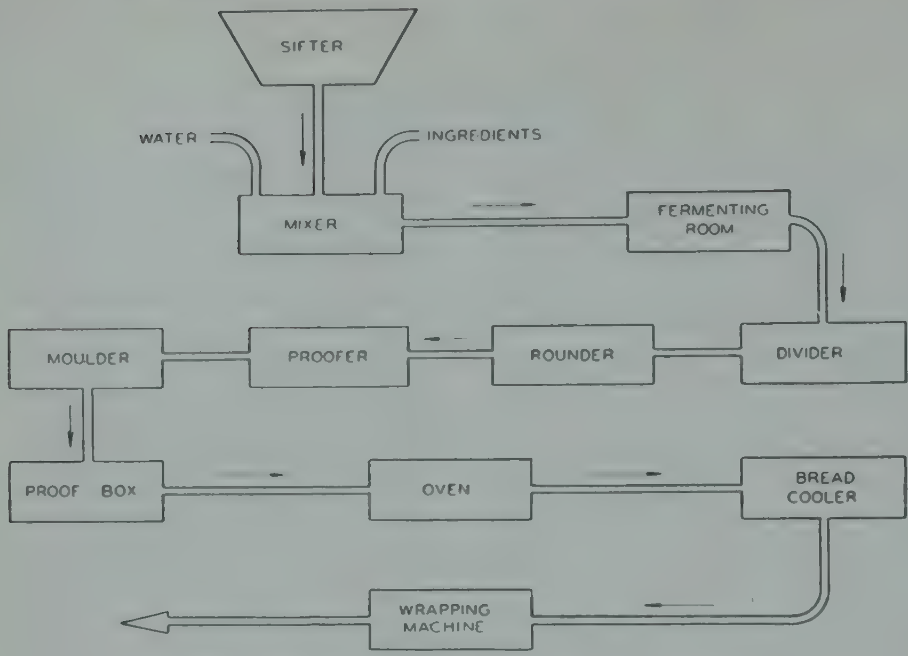


Fig. 1. Steps in Production of Bakery Products.

to the makeup department where it is divided into the desired amount of dough for each loaf; the individual pieces are then rounded out into smooth balls. At this stage the pieces of dough are allowed to rest (ferment) in an intermediate proofer for about 10 to 20 min. The temperature and humidity during this process should be the same as in the fermentation room and can be controlled by air conditioning equipment. However, due to the short length of time that the dough is in this cabinet, few bakers attempt to control conditions at this point. When the pieces leave this proofer they are molded, panned and then put on racks in the pan-proofing box, where they are allowed to ferment and rise to the top of the pan. They are then ready for baking.

In the proof box the temperature should be from 92 to 96 F and the humidity about 80 to 85 per cent, in order to maintain a constant and vigorous fermentation and a moist, not wet, dough surface. Although, throughout most of the year, heating instead of refrigeration is necessary, at times during summer months some type of cooling may be needed. Generally, cold water in coils in the air conditioning unit or cold spray water in the system will suffice. However, a very small mechanical refrigerating unit might be used.

Since bread is put in the proof box in individual pans on racks, it is important that the temperature and humidity be maintained the same throughout the entire box. The desired temperature of the proof box varies slightly with the type of bread being made. Baking and cooling follow.

Refrigeration in Storage

Flour storage. Flour is used in a larger quantity than any other ingredient in bread and sweet yeast goods production, and to a large extent in cake production. Its temperature has a considerable effect on the temperature of the mix. In summer, especially, high flour temperatures may make control of the temperature of the mix difficult. In order to insure the maintenance of flour quality, temperature and humidity of the storage room must be controlled. The temperature should be from 65 to 75 F and the relative humidity 55 to 65 percent. In order to maintain this temperature range, refrigeration is needed in some parts of the country.

Many bakers have flour storage rooms in the basement, as this is the coolest place. Some bakers have reported that the unit heater works well. Its main advantage is

that it supplies adequate ventilation around each individual bag and can be used as a cooling unit in summer. Complete air conditioning is advisable for it controls both temperature and relative humidity. Proper control of the flour storage room not only improves storing conditions but reduces the refrigeration problem at the mixer in summer months.

Storage of other ingredients. Refrigeration at temperatures of 35 to 45 F is very important for storing yeast, butter, liquid milk, some types of shortening, syrups, eggs, fruits, nuts, fillings, prepared mixtures, and other ingredients. In order to produce high quality cakes the baker must control the temperature of ingredients and batters. Most cake bakers are dependent on the control of the temperature of the ingredients for the control of the temperature of the batters.

Other ingredients such as powdered milk, some shortenings, and dry ingredients need not be refrigerated, but should be stored at a temperature of approximately 70 F and relative humidity of 55 to 65 percent. Thus at some times of the year it is desirable and necessary to have the so-called small ingredient room cooled in some manner. Air conditioning is desirable. When these ingredients are controlled at the proper temperature, the refrigeration load during mixing is reduced.

Bakeries use **frozen ingredients** such as eggs and fruits. Freezing cabinets must be available for the storage of these products, as temperatures between 0 and 5 F are desired.

Storage of finished products. Some products which the baker makes, such as custard and whipped cream products and some pies, must be kept cold until they are consumed. They must be refrigerated in the bakery salesroom, thus requiring a refrigerated show case. The temperature of these boxes should preferably be 40 and in no event over 55 F. The products in the box generally supply enough moisture to the atmosphere to maintain adequate humidity for short storage.

Cold ingredient water. It is important for the bread baker to have a supply of cold water for his mixing process. It is evident that the temperature of the mixing water will be an important factor in controlling temperatures in the mix itself. A temperature of 33 F is favored. In some seasons and localities an ingredient water supply at this temperature will take care of cooling of the dough during mixing, if the temperature of the other ingredients is controlled as noted. In other places and seasons it will at least greatly relieve the refrigeration load required during mixing. In **Fig. 3** is shown one method for cooling the ingredient water. The modern tanks in use are enclosed and have removable coils. In cake work it is desired to get the temperature of this water as close to freezing as possible, and in this case a method of agitating the water is used. At the tempering tank, the water temperature can be raised, if desired, by injecting warmer

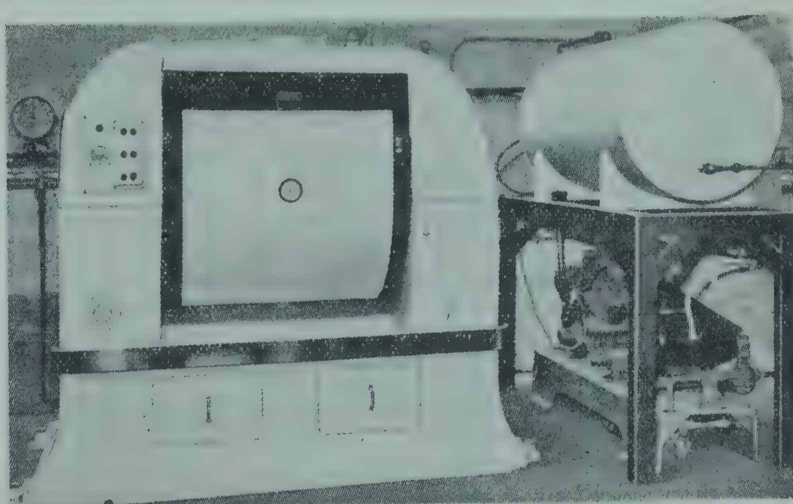
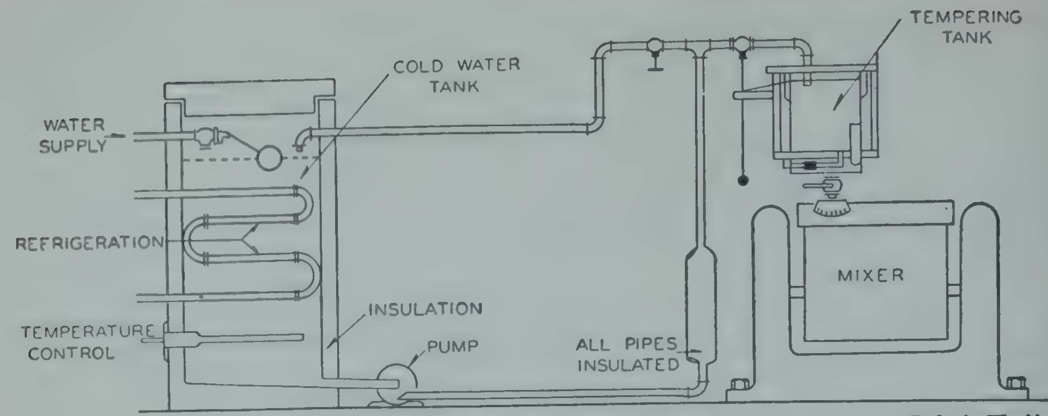


Fig. 2. Direct Expansion Mixer Jacket and Cold Water Tank Operated from One Condenser. Ingredient Water Is Supplied from the Tank and the Direct Expansion Mixer Jacket Cools the Dough During Mixing.



Baker's Weekly

Fig. 3. Method of Cooling Ingredient Water.

water. The tempering tank also serves as a means of weighing the water, or a water meter can be used in connection with a tempering device.

Refrigeration Process

Mixer cooling. Even under the best storage conditions for ingredients, further refrigeration is at times necessary during mixing. If the temperatures of the ingredients, especially the flour and water, are higher than the optimum temperature, a large amount of refrigeration will be needed during mixing.

The following methods are in use in mixer cooling:

1. Cold ingredient water
2. Part of the ingredient water replaced with cracked ice
3. Water circulated through jackets around the mixing bowl
4. Direct expansion of refrigerant around mixing bowl, or
5. A low temperature freezing mixture circulated through the jacket around the mixing bowl.

The general procedure is to have a sufficient supply of cold ingredient water and then, when necessary, to obtain added cooling with ice or a water jacket. When it is necessary to circulate water through the mixing jacket, this may be taken from the same tank used for the cold ingredient water, provided a filter is placed in the line returning from the water jacket. This, of course, is to prevent any scale from getting into the ingredient water supply. It is much better to have a separate tank fo the cooling jacket water, in which case th refrigerant water for the jacket can be re circulated.

Crushed ice can be used effectively but i must be crushed to a point of fine division Care must be exercised, as there is dange of foreign material being chipped from th ice-crushing boxes if they are used.

It is interesting to note that cases o high-speed mixers have been reporte where high flour temperatures in summe have made it impossible to cool the doug sufficiently with cold ingredient water an a water cooling jacket. It is then necessar to add ice also.

Recent success has been attained by us ing direct refrigerant expansion mixin bowl units, where the refrigerant directl from the compressor is allowed to expan around the mixing bowl. Automatic de vices give good control. It is not necessar to use ice in this method. One compresso can be used for the direct expansion mixin bowl unit and for cooling ingredient wate

Somewhat the same effect of a direct ex pansion mixing bowl unit can be obtaine by circulation of a low temperature free ing mixture. By the use of such a mixtur the temperature can be lowered conside ably below 32 F and thus the use of ic can be eliminated, as in the case of th direct expansion mixing bowl unit.

The generally desired temperature of th dough is 78 to 80 F when mixed. Method of computing the load are shown in th next section.

Fermentation room. After the dough

nixed it must be fermented. The time of 'ermentation depends on the type of dough ınd varies from about 2 to 6 hr. For con-isistent results the temperature and humid-ty of the fermentation room must be con-rolled. Temperature governs the rate of ermentation, while humidity affects the ate of evaporation. If humidity is too ıigh, moisture will collect on the dough rom the atmosphere. Generally, it is de-ired that the temperature be 78 to 80 F ınd the relative humidity 70 to 75 percent. The humidity depends to some extent on he degree of air circulation. Correct con-rol of the temperature and the humidity vill allow fermentation periods to be stand-ardized. This humidity control is also im-portant, as in an uncontrolled fermentation oom a dough will lose as much as 1.5 per-ent of its weight, a loss which is expensive vhen production is large.

Air conditioning is desirable for tempera-ure and humidity control. At times cold vater sprays in the air conditioning sys-em will suffice for the cooling effect; how-ever, in other cases mechanical refrigera-ion is necessary. Air conditioning devices of the air washer type, **Fig. 4,** are not un-common.

The fermentation room can be cooled by neans of direct expansion coils from a me-chanical refrigerating machine or by circu-ating cooled water through coils generally ocated on the ceiling. In this arrangement humidifier of some sort is necessary in the oom.

Bread cooling. After bread is baked it cannot be wrapped until the inside crumb has cooled to 85 or 90 F. When bread is cooled on open racks or conveyors on warm days, several hours may be nec-essary for it to reach the proper tempera-ture for wrapping. Moreover, during cool-ing in the open atmosphere, bread will lose 2 to 4 percent of its weight by the evaporation of moisture. This loss of mois-ture is of practical importance, since bread is sold by weight. If the bread is cooled in a room where the relative humidity is high, this loss of moisture is greatly reduced. In a tunnel-type bread cooler, in which the direction of travel is against that of the incoming air, the relative humidity should be 80 to 85 percent for an air temperature of 70 to 75 F. The incoming air should be completely air conditioned. Under normal climatic conditions mechanical refrigera-tion is not needed to cool the air in the humidifying and air washing unit for a bread cooler. Sufficient lowering of the temperature may be obtained by evapora-tion of water **(Fig. 5).**

If a tunnel-type cooler is not available, cooling bread on racks in an air condi-tioned room under the same conditions of temperature and humidity will be helpful. Although there is little difference in time of cooling between atmospheric rack cool-ing at a temperature of 80 F and tunnel-type air conditioned cooling at 80 F, there is a reduction in moisture loss of about 0.25 oz per lb. The time required to cool the bread crumb to 90 F is about 80 min.

Other advantages of air conditioned

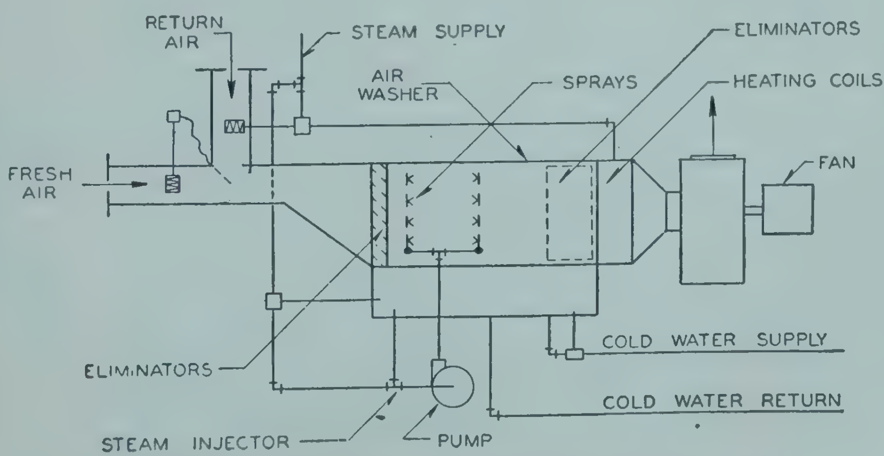


Fig. 4. Air Conditioning System Used in Fermentation Rooms.

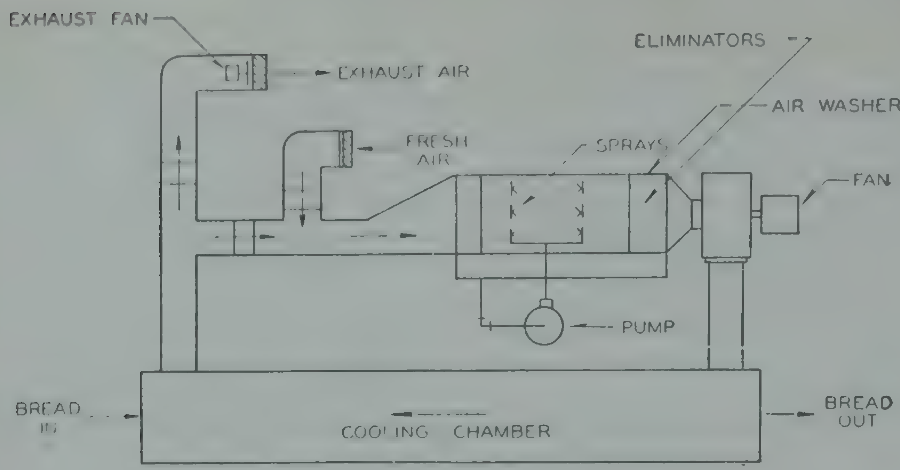


Fig. 5. Bread Cooling Process Using Air Conditioning.

cooling are that it (1) prevents crust checking, (2) reduces crumbling when bread is sliced, (3) makes possible a uniform short cooling period throughout the year, (4) permits standardized scaling due to uniform weight loss, and (5) reduces mold.

Vacuum cooling is another method by means of which bread is allowed to cool in the existing atmosphere for about 40 min and is then placed in a vacuum of about 28.6 in. of mercury. This reduces the temperature of the crumb to 85 F in about 4 min. The character of the crust and the amount of moisture in the bread can be adjusted by the length of time the bread is allowed to stand before entering the vacuum.

All of the data given here under bread cooling apply to white bread and will vary slightly for other types of bread and bakery products.

Retarding doughs and batters. The process of retarding doughs and batters consists of the subjecting of yeast-raised doughs and chemically leavened (baking powder) batters to a sufficiently cold temperature that virtually all activity is stopped. The temperature necessary to accomplish this is about 35 F but it can vary from 32 to 40 F. A relative humidity of 85 percent or more must be maintained in order to prevent drying of the products, but it is important that there be not too much humidity, as condensation is still more undesirable. The refrigeration unit must be of such capacity that it will cool the entire box, loaded with bakery good to the proper temperature in the shorte possible time. Air movement should b slight, to maintain uniform temperatur and to avoid drying such as will occu with rapid circulation.

Since cooling must be as quick as po sible, the baker generally carries his pro ess through until the dough or batter made up into small units, and then refri erates them. When it is desired to bake th goods, it is first necessary to let them stan at room temperature for an interval t warm up and then put them in the pa proof box for a period of fermentation (if yeast product) before baking. Seventy-tw hours is about the maximum length time that products can be so refrigerate and still produce high quality merchandis

The most common products which a handled in this manner are Danish pastr dough for sweet rolls and coffee cake cookies, layer cake mixes, pie crust mixe and bun doughs. The application of r frigeration to these products for retardi the leavening action and making ove fresh goods readily available in the reta bakery is a relatively new development the baking industry. The main advantag of course, is flexibility. Doughs can b made up and placed on the pan for bakin then refrigerated, and baked as they a needed. The advantages of refrigerat doughs have been summarized by Pirr from a survey of bakers throughout t country, as follows: (1) Left-over loss

are greatly reduced; (2) additional bakes become possible when business is brisk; (3) rush orders are easy to handle; (4) oven-fresh goods may be kept in the bakery at all times during the day; (5) night work is greatly reduced, if not eliminated; (6) production schedules are simplified; (7) the week-end rush is relieved; (8) the eating quality of the goods is improved; and (9) sales increase.

Refrigeration processes of this kind are being carried out by the neighborhood **retail baker,** by the house-to-house branches of the baking industry and bakers who have chains of retail stores. There are many types of suitable refrigerators. For the small baker there is the refrigerator which will accommodate bun pans and also compartments for ingredient storage. There are multiple-unit boxes which contain only bun pans and can be added to, to increase capacity, such as are generally used by the larger retailers. Some bakers have cooling rooms, which are reported satisfactory.

In order for retarded dough processes to be successful many precautions must be taken. The temperature and humidity must be right. If a yeast product, the fermentation while the dough is being cooled must be allowed for. If baking powder is used, it must be slow acting. Oven temperature flexibility must be available for baking the varied products. There is still much experimental work to be done on retarded dough processes before the industry wholeheartedly accepts them.

Cold slabs. Before refrigeration was applied for retarding doughs, it was used for Danish pastry and other "rolled-in" products (shortening rolled in) containing a high percentage of shortening. Pie-crust doughs also come under this heading. The doughs are placed in the refrigerator in the form of slabs. Refrigeration is used because it improves the flakiness of these products. The temperature and humidity of the refrigerator should be the same as those used for retarded doughs and batters.

Cooled or air conditioned work rooms are desirable, especially in the summer, for making up whipped-cream cakes, pies and similar products. The temperature of these rooms should be 40 to 45 F. The humidity should be kept high for comfort of the workmen.

General Air Conditioning

In addition to the uses for air conditioning already mentioned, there are some places in the bakery where it is very important, such as for bread slicing and

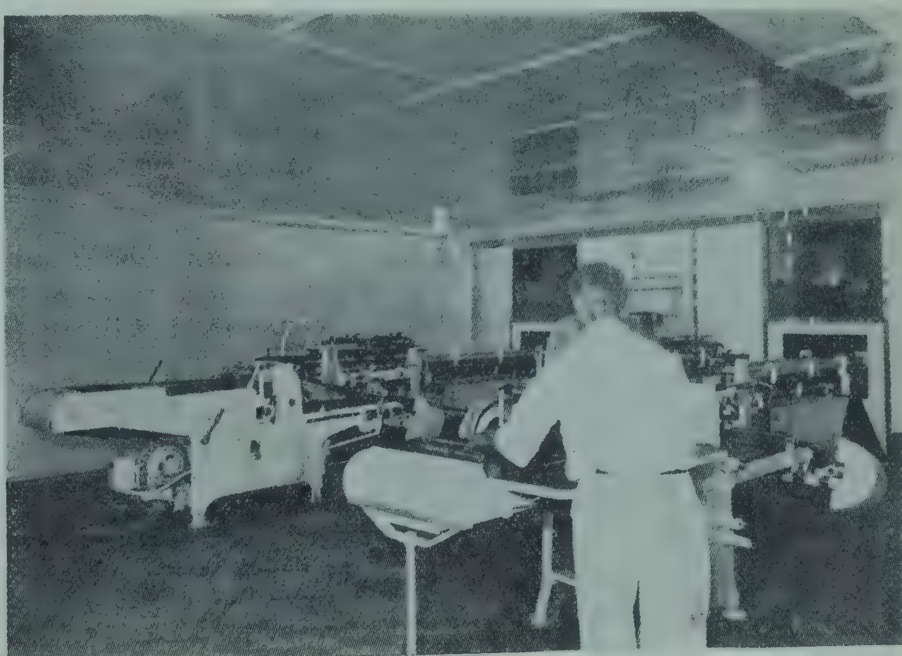


Fig. 6. Air Conditioned Slicing and Wrapping Room in Bakery. An Installation of this Type Helps Prevent Mold Spores from Contaminating the Product During this Operation.

Table 1. Air Conditions Desired in Storage and Processes

	Temp, F	Relative humidity, percent
Flour storage	65–75	55–65
Other ingredients	35–45	—
Ingredient water	32–40	—
Yeast dough when mixed	78–80	—
Fermentation room for yeast doughs	78–80	70–75
Proof box for yeast doughs	92–96	80–85
Bread cooler	70–75	80–85
Retarded doughs in mixer	70 or below	
Retarded doughs in refrigerator	32–40	85
Cake and cookie batters	Variable	—
Cold work rooms	40–45	—
Storage of cream products	40–45	—

wrapping and in the cake make-up room. It is important here for keeping down the quantity of mold spores, bacteria and dust in the air. The system should operate so as to remove mold spores and bacteria from the air at all times. Of course, where it is economically possible, it is advisable to air condition the entire bakery and the sales rooms.

Table 1 summarizes the optimum temperatures and humidities desired at various points in the bakery, as mentioned throughout this chapter.

Mixer Load Calculation

At the mixer, electrical energy is converted into mechanical and then into heat energy, equivalent to about 85 percent of the electrical input to the motor. Knowing the total quantity of electrical energy used during the mixing time, it is possible to calculate the number of Btu developed in the mixer, or the number of horsepower required to mix the dough. Averages of many different doughs show that it requires about 4 hp (42.44 Btu per min) for every 100 lb of flour in the dough for the straight dough method. One can use this average figure to give an approximate estimate of the number of Btu developed in the mixer. For example, a straight dough containing 500 lb of flour and mixed for 6 min will develop $4 \times 5 \times 6 \times 42.44 = 5090$ Btu. Another source of heat in the mixer is the heat of hydration of the flour, which is approximately 6.5 Btu per lb.

In addition, one must consider the following factors when determining the amount of **refrigeration for the mixer:** (1) Design of the dough mixer, (2) radiation to and from the mixer, (3) speed of the mixer, more refrigeration being required for the faster speeds, (4) consistency of the dough, more refrigeration being required for stiffer doughs, (5) size of the dough, more refrigeration being required for the larger doughs, (6) length of the mixing period.

Frozen Bread

The freezing of bread to retard staling has been investigated quite thoroughly and has been found to be satisfactory. At the freezing point, bread becomes stale faster than at room temperature. Below the freezing point, bread staling is retarded. At about −10 F bread remained good for 20 days, and at about −30 F it remained good for 90 days. Bread staling is not only loss of moisture, but also a change in the form of the starch. X-ray studies show that, as bread or other yeast-raised products leave the oven, the starch has both a crystalline and an amorphous component. As the product ages, the amorphous component disappears and finally all of the starch exists in the crystalline form. This makes the product harsh in texture.

A large-scale eating test showed that month-old bread frozen at −10 F rated almost as high as fresh bread. All of the experiments reported so far have been on sharp freezing methods in commercial freezers.

The bread must be wrapped in moisture-proof wrappers throughout the freezing and thawing periods, the temperatures must be low, and sufficient time must be allowed for the thawing.

The freezing of other bakery products, such as cakes, pies, and pastries, has also proved successful and, in a small way, some of these products are being merchandised at the present time. From an economical standpoint, it seems more practical to freeze cakes, pies, and pastries than bread products.

If you searched this chapter for something which was not found in it, please let the editors know.

29. BREWERY REFRIGERATION

EVERY step in the manufacture of beer or ale is carried out at carefully **controlled temperatures.** In the preparation of wort or unfermented beer, temperatures are above atmospheric and obtained with steam; after the wort leaves the brew kettle and the spent hops are removed, the hot wort is cooled. From then on, until the barreled, bottled, or canned beer is shipped, all operations are at sub-atmospheric temperatures, requiring refrigeration, except that bottled and canned beer are pasteurized as a part of the final bottling and canning process. In addition to process temperature control, hops and yeast are stored under refrigeration.

In addition to temperature control, the other prime requisite in brewing is **sterility.** Since the reactions in the brewing process are organic, promoted by enzymes, or unorganized ferments secreted by living organisms, careful precautions must be taken to insure that only the right organisms, secreting the desired enzymes, are present at any stage. All equipment must be capable of being cleaned thoroughly and easily, and contamination must be guarded against at all points, including the air within or introduced into the rooms where yeast, wort, or beer is exposed.

Besides Fahrenheit and Centigrade temperatures, a third temperature scale, Reaumur, is used in brewing. On this scale the freezing point of water is 0 R and the boiling point at atmospheric pressure is 80 R. Therefore,

$$R = .8C = 4(F-32)/9$$

H. B. MATZEN, Reviewer Chapter 29. Educated at Stevens Inst. of Technology, ME, 1907. Formerly, Specialist in Air Conditioning and Refrign. Industrial Applications, Carrier Corp., 1913–35; York Corp., 1935–38; Brewery Applications, Jos. Schlitz Brewing Co., Milwaukee, Wis.; Brewing Corp. of America, Cleveland, Ohio; Jacob Ruppert Brewing Co., New York; P. Ballentine and Sons, Newark, N.J.; John F. Trommers Brewing Co., East Orange, N.J.

Member, Amer. Soc. of Refrig. Engrs., 1921.

At present, Consulting Engineer, Frank A. McBride Company, New York, 1938 to date.

The unit of volume measurement in the brewery is the barrel, defined as 31 gal, which is 4.144 cu ft **Fig. 1** shows the chief steps in beer making.

Chemical Aspects

The principal brewing reaction under refrigeration occurs during the fermenting period in the conversion of maltose ($C_{12}H_{22}O_{11}$) to ethyl alcohol (C_2H_5OH) and carbon dioxde (CO_2) according to the following equation:

$$C_{12}H_{22}O_{11} + H_2O = 4C_2H_5OH + 4CO_2$$

Maltose + water = alcohol + carbon dioxide + heat. The heat of reaction is 280 Btu per lb of maltose. The molecular weights are: maltose 342; ethyl alcohol 46; carbon dioxide 44.

Thus 1 lb of maltose forms $4 \times 46/342 = .538$ lb of ethyl alcohol and $4 \times 44/342 = .515$ lb of carbon dioxide. This reaction is promoted by the **enzyme zymase,** secreted by yeast. The zymase in effect acts as a catalytic agent, and is not consumed by the reaction.

Yeast may be **bottom fermentation,** in which case it is heavier than the fermenting liquid, or **top fermentation,** in which case it is lighter. Bottom fermentation yeasts are always used in making lager beer, top fermentation in making ale. In either case, the cooled wort is pitched with some yeast to start fermentation, and this yeast grows during the fermentation period. Some of it sinks or rises, as the case may be, while some of it remains in the body of the fermenting liquor, held there by the circulation set up by the escape of the CO_2 formed, and by the thermal currents. With bottom fermentation yeast, when the beer stops fermenting the yeast sinks to the bottom of the fermenting tank, and the beer is drawn off from above it, after which the beer in the bottom of the tank, containing the yeast, is recovered by filtration. With top fermentation yeast, the yeast is skimmed from the surface of

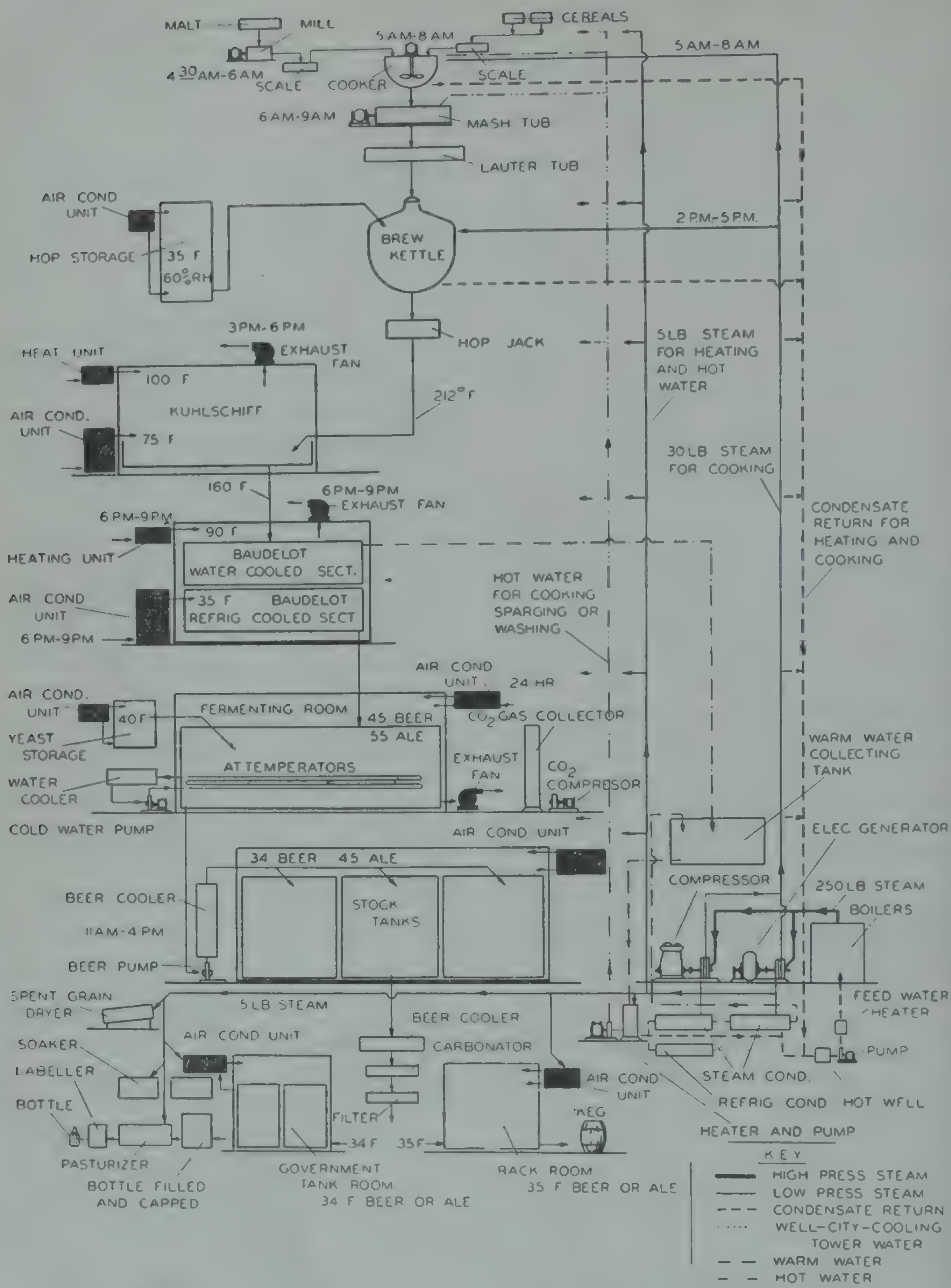


Fig. 1. Functional Diagram of Modern 500-Bbl Brewery.

the ale. The ale which is skimmed off with it is recovered by filtration. In either case, part of the yeast recovered is used for the pitching of future brews. Fermentation with bottom fermenting yeasts is carried on at a temperature of the liquid from 45 to 55 F, and with top fermentation yeasts at from 55 to 65 F. These temperatures are controlled by cooling coils within the liquid in which cold water or brine is circu-

lated. These coils are known as **attemperators** and are usually hand controlled.

The concentration of wort is measured by the **saccharometer**, which is a hydrometer graduated to read in per cent of solids measured as maltose in solution in water (Table 1). One of the standard instruments is the Balling saccharometer and the reading is referred to either as "percentage of solids by saccharometer" or "percentage Balling." The same instrument is used during and after fermentation and is an accurate measure of density and weight per bbl., but is no longer a measure of solids except indirectly, because the solution now contains alcohol, which is lighter than water. The change of saccharometer is called the apparent **attenuation**, and the real attenuation is always less than the apparent.

For engineering computations, the real attenuation may be taken as 81 percent of the apparent, which is a close approximation. Then 81 percent of the difference of solids shown in Table 1 for the saccharometer readings before and after fermentation represents the weight of maltose fermented per barrel; this weight times 280 gives the heat of fermentation per barrel, and the difference between original solids and weight fermented per barrel gives the final solids per barrel. For engineering computations, it may be assumed that there is no change of volume during fermentation.

The heat capacity of beer per pound may be taken as the same as that of the wort from which it was made; the weight per barrel is of course decreased according to the apparent attenuation.

Wort Cooling

The purpose of wort cooling is to prepare the wort for the **fermentation** process. Temperature reduction is not the sole purpose. Precipitation, coagulation, oxidation, aeration are the associated effects which are considered essential to good fermentation and a superior quality of finished product.

Hot wort comes from the brew-kettle, via the hop-strainer, to collecting tanks. These may be large shallow pans, called **kuehlschiff**, enclosed in a room in which the wort is allowed to stand for a period, and cooled by blowing clean sterile air over the surface. This cooling is done entirely by evaporation and the wort is cooled to at least 160 F. Precautions must be taken to insure a sterile atmosphere when using a kuehlschiff, to avoid contamination. It is essential to prevent condensation of the vapors leaving the kuehlschiff from dropping into the wort. This is accomplished by blowing a stream of clean heated air along the ceiling above the kuehlschiff and exhausting the vapor laden air to outdoors.

The wort at about 160 F flows by gravity over the wort cooler, generally located directly below the collecting tank. The wort is cooled to the temperature for starting fermentation, 45 F for lager beer, 55 F for ale.

Wort coolers are usually of the **open** or **Baudelot** type. They are generally preferred, as being easier to clean and giving more satisfactory aeration of wort during cooling. The wort flows by gravity over the outsides of horizontal pipes arranged in stands. The cooling medium flows successively through the pipes from bottom to

Table 1. Total Solids, Lb per Barrel

Saccharometer reading, % solids	Specific gravity	Weight per bbl., Total	Weight per bbl., Solids	Specific heat, Btu/lb
0	1.0000	258.7	0.00	1.000
1	1.0039	259.7	2.60	.993
2	1.0078	260.7	5.21	.986
3	1.0118	261.8	7.85	.979
4	1.0157	262.8	10.51	.972
5	1.0197	263.8	13.19	.965
6	1.0238	264.9	15.89	.958
7	1.0278	265.9	18.61	.951
8	1.0319	267.0	21.36	.944
9	1.0360	268.0	24.12	.937
10	1.0402	269.1	26.91	.930
11	1.0443	270.2	29.72	.923
12	1.0485	271.2	32.55	.916
13	1.0528	272.4	35.41	.909
14	1.0570	273.4	38.28	.902
15	1.0613	274.6	41.18	.895
16	1.0657	275.7	44.11	.888
17	1.0700	276.8	47.06	.881
18	1.0744	277.9	50.03	.874
19	1.0788	279.1	53.03	.867
20	1.0833	280.2	56.05	.860

top, giving a step-by-step approximation to **counter-flow.** The tubes using water as a cooling medium are solid copper or some alloy inert to wort, the tubes using ammonia or brine are polished steel, although copper-clad steel, or alloys inert to both wort and ammonia or brine, may be used. There is a distributing trough at the top of the stand, and a broad shallow collecting pan at the bottom. All surfaces in contact with the wort except the ammonia section tubes are inert metal, and all surfaces are built to be readily accessible and easy to clean, corners are rounded, etc. After each brew the cooler is washed and scrubbed. To avoid contamination the cooler is placed in a closed room, through which clean washed or filtered air is circulated.

The size of wort coolers is determined by the rate of wort cooling, the rate of water flow, and the temperature difference employed. A brew, which may vary in size from 50 to 700 bbl, or even larger, is ordinarily cooled in from 2 to 4 hr. Open type coolers are made in stands up to about 20 ft long. Where more than 20 lin ft of stand are required, the cooler is divided into two or more stands, operated in parallel.

Open coolers are best operated with a wort flow of 3 to 3.5 bbl per hr per lin ft of stand. At higher rates there is a tendency to splash, and either the height (number of tubes per stand) becomes excessive or temperature differences become excessive, requiring increased refrigeration. The coefficient of heat transfer varies with the velocity of water in the tubes, and the flow of wort over the tubes.

In proportioning a wort cooler, the principal objects to be attained are:

1. Minimum refrigeration
2. Minimum cost of water used for this purpose
3. Recovery of as much of the heat as can be advantageously utilized.

Use of Cooling Water

Minimum refrigeration is usually obtained by cooling the wort as far as possible with available **cooling water** before it comes onto the refrigerated section. It should usually be cooled to not over 10 F above the temperature of the coldest water supply available. In evaluating the cost of refrigeration, it should be borne in mind that with direct expansion or brine wort cooling, the **peak refrigeration load** is set while cooling wort, and any increase of refrigeration requires not only the energy to produce it, but increases the size of the refrigerating plant, and with electric drive increases the **demand charge.** This cooling is usually first done by available water, recovering as much heat as possible, and storing the warm water for the next brew and/or for washing or other purposes. At least two barrels of water are required, in the operation of a brewery, for each barrel of brew.

The cost of water is chargeable against the wort cooler only when the water is not used afterwards for some other purpose, such as brewing, washing, or boiler feed. When extra water must be used to save refrigeration, account should be taken of the saving in water required for ammonia condensing; or if a constant amount is used for this purpose, of the saving due to reduction in condensing; or of the saving due to reduction in condenser pressure because of the smaller temperature rise in the condensing water.

Any useful recovery of heat saves steam which would otherwise have to be made; and in an **economic balance** this saving must be credited to the cooling. This heat may be utilized for heating water for the next brew, for heating wash water, for heating boiler feed, or for heating water for any other use in the plant.

The size of, and therefore the investment in the wort cooler, is determined by the above items, the rates of flow, and the arrangement of water circuits. The water circuits, in turn, are related to the use of hot water and the cost of water, and the number of sources and temperatures of the water. In general, there will be either one or two **water supplies,** which may be at the same temperature or different temperatures.

With one supply, if hot water of a definite temperature (as for brewing) is required, a water section can be provided which will heat all the water to this tem

perature. The quantity of water must be such that the heat required to raise it through its temperature range equals the heat given up by the wort in cooling through its temperature range on the water section. If less hot water than this is required, it is possible to decrease the size of the cooler by putting more water through the first part of the water section, and bleeding off the excess after it has passed over part of the surface. By regulating the inlet and bleed-off flows, the right quantity and temperature of water can be obtained. If more hot water is required than can be heated by the wort, so that steam must be used for water heating in any case, all of the water can be heated through a smaller range, and a smaller cooler will be needed.

With two water supplies, a variety of conditions may be encountered. With both at the same temperature, but one more expensive than the other (as city water for brewing and treated and/or filtered river water for washing), the water section can be divided in two parts, and the amount of more expensive water required in process heated through the required range in the section having the hottest wort. The remaining cooling can then be done with the cheaper water. With the cheaper supply colder (as city water for brewing and well water for washing), the same scheme can be used. With the more expensive supply of lower temperature (as city water for brewing and cooling-tower water), the water section can be split in three parts, the required expensive water put through the first and third and bypassed around the second, through which the cheaper warmer water is run. With greater hot water requirements than heat available from wort cooling, as much of the cooling as possible should be done with the colder water, to give the maximum temperature difference, and therefore the minimum cooler surface.

Refrigeration Storage

To reduce refrigeration demand (but not total quantity), wort cooling is sometimes done with **stored refrigerated water.** In this case, water is refrigerated continuously (or for a greater period than the wort cooling period), and stored at about 35 F, in large tanks in refrigerated space. This requires the addition of cold water storage tanks and a Baudelot cooler for the water, but reduces the size of the refrigerating plant required, and in an electrically driven plant, cuts the demand charge. With this scheme, the entire wort cooler is water section. To obtain minimum refrigeration, water from the coldest supply should be refrigerated, and the heat capacity per degree of the water through the refrigerated section should be equal to the heat capacity per degree of the wort. If the heat capacity of the water is greater, it will cool the wort through a greater range while it is rising to its initial temperature, thus requiring more refrigeration. If the heat capacity of the water is less than that of the wort, it will require an unduly large cooler surface, due to the small temperature difference, or if the heat capacity is too small, the required cooling will be impossible.

Other methods of providing cold water for cooling wort are to form **ice on coils,** or to make ice in **flake form** during off-peak refrigeration periods and then melt it during the wort cooling period. All of these methods have primarily the purpose of reducing the capacity of the refrigerating plant and making maximum use of the refrigerating plant during off-peak periods. Where electrical current is purchased this also assists in reducing the maximum demand and therefore the electrical costs, in addition to a possible lower investment in refrigeration equipment.

Since every brewery must of necessity have a steam plant for the brewing process, and since hot, warm, and cold water, power and refrigeration are required, a thorough study of heat balance and cost of providing these is essential in order to produce the final finished product at minimum cost.

Fermenting Rooms

Fermenting tanks may be either open or closed, of wood, steel or concrete. Most fermentation is done in **open fermenters** of wood; **closed fermenters,** usually of steel, are used (a) for collecting CO_2 for carbonating, and (b) for kraeusening, i.e., second-

ary fermentation under pressure for self-carbonation.

The refrigeration problem in the fermenting room is (a) to maintain the desired temperature in the room and in the beer; (b) to maintain an atmosphere in which men can work in comfort and safety. The load encountered consists of:

1. Removing heat of fermentation
2. Removing heat leakage and infiltration through walls, floors and ceilings
3. Removing heat and excessive moisture introduced by men, lights and motors, opening of doors, and cooling of wash water
4. Conditioning make-up air which must be introduced to maintain the CO_2 concentration within the required limits for proper ventilation for the workmen.

The load is distributed between the room cooling and/or the air conditioning apparatus and the attemporator system. The brew runs from the wort cooler to a starting tank where it is pitched with yeast. When the fermentation is well started, the brew is transferred to a fermenting tank. During fermentation the temperature rises slowly at first, then at an increased rate and finally at a decreasing rate. This cycle of fermentation and temperature is controlled by the brewmaster.

The heat of fermentation is controlled by removing heat leakage through the tanks and by passing refrigerated water through the attemperator coils located in the fermenting liquid.

For a given brew the rate of fermentation varies for each day of its fermentation period. However, since the brews are usually delivered to the fermenting tanks at a uniform rate daily, the total heat of generation as a result of maltose conversion is practically a daily constant. Therefore, for a given resultant percentage of alcohol content, the heat generated is practically constant and is equal to 280 Btu per lb of maltose converted per bbl of brew. The amount of CO_2 produced per bbl is arrived at in the same manner.

Of the total CO_2 produced per bbl, as stated before, some remains in the fermenting liquid, some is collected for later carbonization and the balance spills over into the fermenting room. The amount that spills over must be diluted so as to keep the concentration within the room to below 3 percent for the comfort and health of the workmen. This is done either by introducing a constant quantity of outside air and exhausting a like amount, or by exhausting only and allowing a like amount to find its way into the room by infiltration.

As previously stated, each pound of maltose fermented produces 0.515 lb CO_2. The beer retains about 0.2 percent of its own weight of CO_2 and the balance is either collected from closed fermenters or escapes to the fermenting room from the open fermenters. On the average about 1 lb per bbl is collected for the carbonating system, or with kraeusening about .5 lb per bbl is retained in the closed fermenters. This is in addition to the 0.2 percent retained in the open fermenters. The remainder escapes to the fermenting room.

One lb of CO_2 at the fermenting room temperature occupies about 8.3 cu ft; consequently for each pound escaping into the room there must be introduced 8.3/.03 =277 cu ft of outside air to keep the concentration at 3 percent. This air introduced into the fermentation room should be filtered and washed and further treated if necessary, in order that no outside bacteria or foreign odors may be brought into the fermenting atmosphere.

While higher percentages of CO_2 will support respiration, they are uncomfortable, lead to shortness of breath, headaches, etc., and are likely to be blamed for any ailments of the men working therein. In modern equipped fermentation rooms air conditioning apparatus is used to maintain the desired temperature in the room and to maintain an atmosphere in which the men can work in comfort and safety. This then leaves the attemperators to control the heat of fermentation.

Since air is distributed and circulated by the air conditioning apparatus, it is of utmost importance that this air be so distributed and circulated that no high velocity streams of air come either in contact with the tops of the open fermenting tanks

mpinge on the sides of the tanks, since his may cause excessive currents of liquid vithin the fermenters due to excessive emperature difference, or foam may be arried from the top of the open tanks and prayed over the ceiling and side walls of he room. Therefore great care must be iven to the location of outlets in relation o the tanks and such form of outlet must e used as will cause the minimum disurbance.

Attemperator coils are usually made of opper pipe, following the inside circumerence of the tank. Water at 34 to 36 F is sually figured on a 2 to 4° temperature ifference in and out. The coils are usually quipped with hand valves so that the rewmaster can control his fermentation ycle.

Beer Cooling

After completion of fermentation the eer passes to the stockhouse through cools, which cool it from 45 F (ale 55 F), to bout 34 F (somewhat higher with kraeuning) and to about 45 F for ale. The beer usually stored in large glass-lined steel nks and allowed to age for a period rangg from not less than four weeks to sevral months at this temperature.

The beer coolers are of the double-pipe pe with beer or ale in the inside pipe for onvenience of cleaning. These coolers may ther use brine or direct expansion reigerant. The coefficient of heat transfer be expected is shown in **Table 2.**

Whenever the beer or ale is transferred om one storage room to another, such as the racking or government cellars, or etween cellars kept at the same temerature or lower, it is usually cooled to fset any possible **temperature rise** due to this transfer. There is no standard for this cooling time; it is usually done during off-peak periods.

Table 2. Heat Transfer in Beer Coolers, Btu per sq ft hr F

Velocity of beer, ft per sec	Transmittance U
1	75
2	95
3	113
4	129
5	143

The refrigeration load in the beer (or ale) **storage cellars** is made up of heat leakage through walls, floors and ceilings, heat introduced by men, lights, opening of doors, wash water, infiltration, and with kraeusening the heat of secondary fermentation. These items are figured in the same way as the same items were for the fermenting rooms. The load can be carried satisfactorily by either coils or unit coolers with forced air circulation.

In the **racking room** the beer is placed in barrels (beer kegs of 31 gal capacity) for dispensing and shipping. The beer is usually cooled 2 or 3 F below its storage temperature by a beer cooler, carbonated (if not kraeusened), filtered, and then racked until ready to be loaded on trucks or railroad cars. The racking room is usually held at 32 to 34 F and the refrigeration load is made up of the same items as the beer storage load plus the load for cooling the barrels.

Beer or ale that is finally bottled or canned is transferred to calibrated tanks provided with locked stop-cocks in what are known as **government cellars.** These tanks are known as government tanks and are sometimes placed in the regular beer storage cellars. Filling and emptying of these tanks is under government supervision.

The temperature in these cellars is maintained at from 32 to 34 F and the load is made up of the same items as the beer storage load.

Storage problems. Hops are a very important ingredient in the brewing process. They are usually purchased in large quantity and stored for relatively long periods. As they are vegetable matter, susceptible to deterioration by fermentation under favorable temperature and humidity conditions, it is quite important to arrest this fermentation to preserve the texture, quality and aroma. This is done by storing them (usually in burlapped bales of 200 lb each) in a room maintained at 34 F and a relative humidity of 65 percent.

The refrigeration load is essentially heat leakage through walls, floor and ceilings,

and the load of cooling the bales to the room temperature plus infiltration. Since but a small quantity is removed at any one time, the people and light load may be neglected. This is usually taken care of with a unit cooler with forced air circulation and provided with temperature and humidity control.

Yeast is purchased from a manufacturer, or cultivated on the brewery premises, and is also obtained as a result of the fermentation process. It is kept in a small room and maintained at about 38 F. The refrigeration load is made up of the same items as in beer storage.

Since CO_2 is used for final **carbonization** and since sufficient CO_2 can be collected in most breweries from the fermentation process, it is necessary to store it until ready to be used. This can be done either by storing in the gaseous or the liquid state. Storing in the gaseous state requires considerable space for tanks and special CO_2 compression equipment. Recently CO_2 has been stored in the liquid state with a very large saving in space. The gas is firs compressed to 150 lb per sq in. and then cooled by refrigeration to condense the ga to a liquid and stored in steel tanks in a heavily insulated room maintained at a low temperature. The volume for liquid storag is approximately 1/46 that required fo storage in the gaseous state.

Since a brewery requires steam, power water and refrigeration in the process o manufacturing and since the process is batch process with the peaks of the fou necessities occurring at various period (not simultaneously), it is extremely im portant that the heat units in the stear be converted to the maximum use and a much by-product as possible be obtained in order to reduce the manufacturing cos to the minimum. Each brewery therefor requires its own particular study in orde to reduce the equipment required, as wel as the operating and maintenance costs, t a minimum.

If you searched this chapter for something which was not found in it, please let the editors know.

30. REFRIGERATION IN WINE MAKING

REFRIGERATION requirements for wine growing can be divided roughly ıto two classifications, (1) that needed or control of temperature during fer-ıentation, and (2) that needed to hasten ıe removal of the excess potassium bi-ırtrate and cold coagulable materials in ewly made wine. The purpose of the re-igeration, and the methods and equip-ıent used, differ radically under these two assifications.

A possible third classification must be oted. Heating red grapes to obtain color ctraction and to permit pressing prior to rmentation, thus keeping the pomace out the fermenting cellar proper, almost cer-inly will be widely adopted in short time. lash heating from field heat to 190 F ithout holding and flash cooling back to F is a requirement for satisfactory op-ation. This cooling requirement can only met satisfactorily by mechanical refrig-ation.

The full refrigeration load under each assification is a characteristic of the in-vidual winery. It is dependent upon such great number of variables that an exact aluation for a particular winery can ly be arrived at through careful study that winery's wine-growing methods.

Wine growing methods are in a state of ıx. The role adequate refrigeration can ay in modern wine growing is becoming eadily better recognized by management. inery managements that were formerly tagonistic toward new technological development are now slowly applying such developments to their practices. The combined result will be much expanded use of mechanical refrigeration by this industry.

George L. Marsh, Author Chapter 30. Born in San Francisco, Calif., and received his MS from the University of California.
Author of "Heat Transfer in Foods during Freezing and Subsequent Thawing," *Ind. Eng. Chem.*; "Heat Transfer in Foods," *Refrig. Eng.*; "Effect of Cold and Freezing Storage on Wine Composition," *Ind. Eng. Chem.*; Commercial Fruit and Vegetable Juices, Univ. of Calif. Circular 344; Chapter 28, 1946 Applications Vol., ASRE Data Books. Co-author "Fruit and Vegetable Juices," Avi Publishing Co. Member Inst. of Food Technologists; Sigma Xi; Gamma Alpha; Alpha Zeta; AAAS; Society of American Enologists; Secy. Technical Advisory Committee of the Wine Institute.

Cooling Requirements of Fermentation

Wines are greatly affected by the temperature of fermentation. High temperatures during fermentation are detrimental to quality, from the standpoint of both initial quality and keeping quality. In effect, high temperatures can result in complete loss of the wine as they inhibit the growth of wine-yeasts, but favor the growth of disease-producing bacteria. Control of temperature is, therefore, a basic wine-growing problem.

It was formerly thought that properly conducted fermentation was carried out at a temperature which combines the beneficial effects of heat in the extraction of color, tannin, and body, with those of a cool fermentation in producing bouquet, freshness, and maximum amount of alcohol. In this respect, experience has taught that red wines should be maintained at 85 F or lower and white wines at 80 F or lower, by employing refrigeration to dissipate the heat generated during the fermentation.

Recently enologists have demonstrated distinct advantages are gained in conducting the fermentation at lower temperatures than those noted above. It also appears that controlled uniform temperatures of fermentation for both red and white grapes alike are more desirable than the semi-controlled fluctuating systems used at present. Reducing the red grapes to fully colored juice by the method noted permits the wine grower to ferment both red and white grapes by the same procedure. Temperature control thus becomes simplified and best furnished by methods using mechanical refrigeration.

The precise amount of heat generated during fermentation of a gram molecule of

sugar is not known. The value most commonly used is one determined by Bouffard, who showed that 180 g of sugar give off 23.5 kg cal during fermentation. (1 lb sugar gives off 234 Btu). On the basis of this figure, each percentage of sugar by weight generates enough heat in fermenting to raise 100 parts 2.34 F. Since degrees Balling or Brix equals percentage sugar by weight, it follows that for every degree Balling that a must (crushed grapes) decreases during fermentation sufficient heat is produced to raise the entire mass 2.34 F. Thus a must of 24 Balling in fermenting is capable of generating enough heat to raise its temperature 24 $\times 2.34 = 56$ F. Such a must, commencing fermentation at 70 F, would reach the inactivation temperature for the yeast (100 to 105 F) while it still contained 10 percent of fermentable sugar, provided no heat losses occurred during this period.

Much of the heat generated during fermentation is lost by radiation, however. Data are available which would indicate that during the full course of the average fermentation, about 50 percent of the heat generated is so dissipated. The exact amount depends upon the size and shape and the material of which the fermenter is constructed and also upon the outside air temperature. During the initial stages of the fermentation (first half-stage) the rate of heat loss by radiation is much less than that indicated, however, and has been shown by experiment to be 33 percent on the average. The calculated cooling requirements for fermentation should be based upon this figure, rather than the former.

Assuming average conditions, and existing practices, calculations show the minimum cooling requirement for fermentation of table wines to be 150,000 Btu per 1,000 gal. To allow for grapes of higher sugar concentration or with more field heat, a figure of 250,000 Btu per 1,000 gal or 50,000 Btu per ton should be used for load calculation. The above figures are too high for dessert winery practice. The amount of sugar allowed to ferment differs greatly for the various wine types produced. Under average conditions, the cooling requirement for fermentation of dessert wines should only amount to 50 percent of thos[e] cited above.

The minimum cooling requirements fo[r] fermentation of table wines under condi[-] tions of constant temperature are esti[-] mated to be 225,000 Btu per 1,000 gal a[t] present. A figure of 400,000 Btu per 1,00[0] gal should be used for load calculations. Load calculations for this plan of operatio[n] under dessert winery practice should onl[y] be attempted after a thorough study of [a] detailed operating program.

In a winery crushing 50 tons of grape[s] per day for table wines there will be on th[e] average about 10,000 gal of must to b[e] cooled daily. This will require refrigeratio[n] facilities capable of removing 2,500,00[0] Btu in the time period chosen by the wi[n]ery operator. If cooling operations are ca[r]ried out on a 12-hr basis, about 208,00[0] Btu per hr of refrigeration will be re[-] quired. Water in the amount of 2,500 g[al] per hr rising 10 F in temperature will sa[t]isfy the required refrigeration load. Mo[st] wineries are situated where they can o[b]tain water at 60 F in adequate quantitie[s] or where water from a cooling tower wi[ll] reach 60 F, or lower. Units employin[g] water as the cooling medium are therefo[re] the most commonly used devices for th[is] purpose.

This tendency to use water as the coo[l]ing medium has persisted even where th[e] cooling load cannot be adequately fu[r]nished by the available water supply or b[y] water from a cooling tower. Extreme fle[x]ibility is the principle advantage. The r[e]frigerating capacity of the available wat[er] is increased by lowering its temperatu[re]. Storage reservoirs assist to satisfy t[he] required refrigeration load. Recently hi[gh] efficiency, mechanically refrigerated wat[er] coolers have been used for this purpo[se] **(Fig. 1).**

Methods of Cooling Fermentations

Systems using water as the cooli[ng] medium may be divided roughly int[o] (1) those in which the cooling coils a[re] mounted directly within the ferment[er] **(Fig. 2)**, and (2) those in which the cooli[ng] coils form a separate unit and throu[gh] which the fermenting must is pumped i[n] counter-current direction to flowing wat[er]

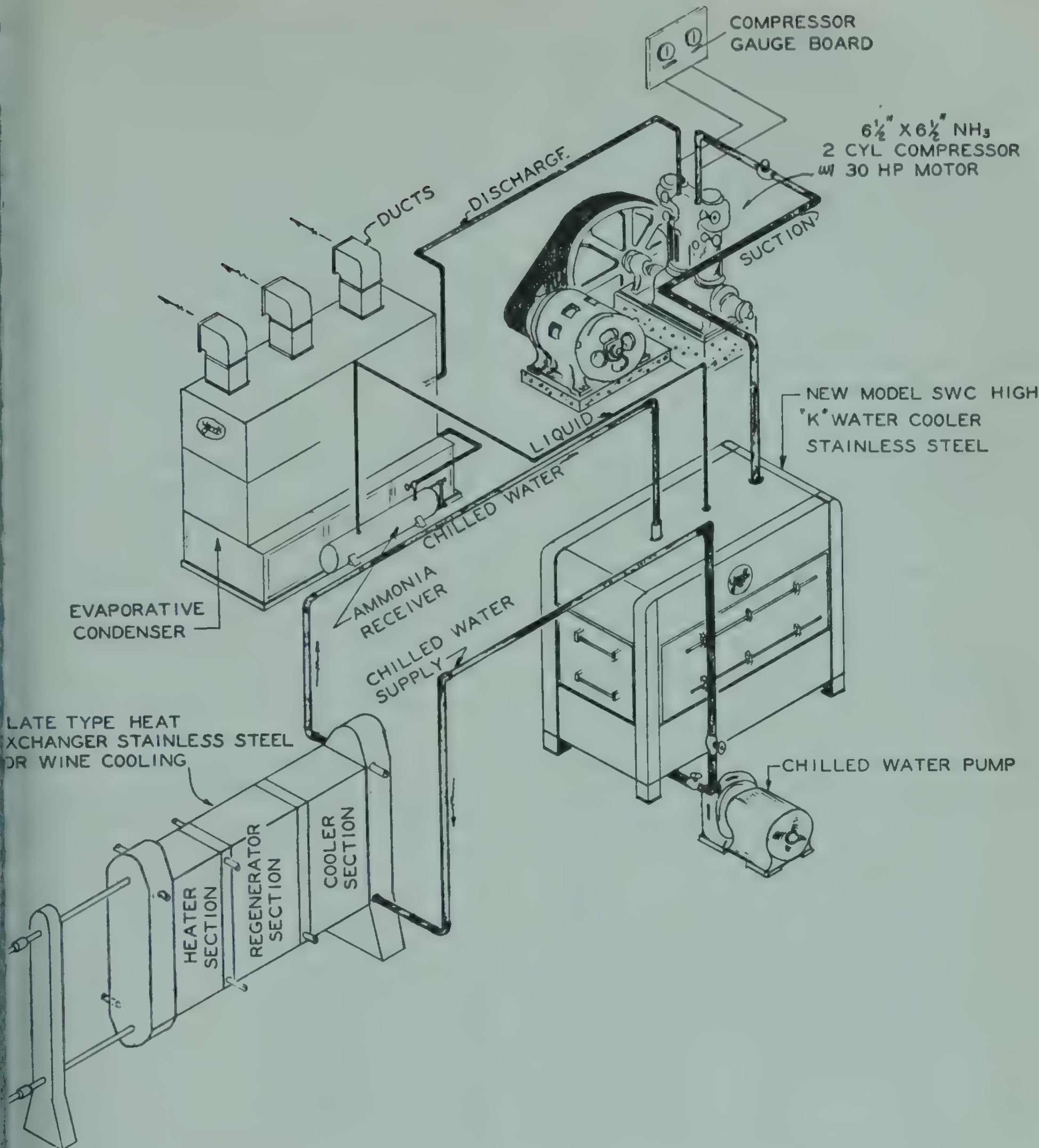


Fig. 1. Refrigeration System for Cooling and Chilling Wines.

ig. 3). The former method is most comonly used by the dessert wine industry ile the latter is used most frequently the wineries producing table wines.

Both systems were in use prior to Proition but failed to give completely tisfactory results. The system of placing ls in the fermenters particularly reved much unfavorable criticism as it atly interfered with cellar practice. The of a red wine fermentation requires a ice daily pushing under the surface of fermenting liquid ("punching") for color extraction. The centrally located coils and their supporting frames seriously interfered with this essential operation. Although the coils acted to control the temperature of the fermenting liquid, they did not control nor successfully remove the greater amount of heat to be found in the cap. The system, therefore, failed to accomplish one of its main purposes, and wines of high volatile acidity were frequently encountered in spite of the cooling provided.

The comparatively favorable results

obtained with the system of placing coils in the fermenting tank at present has resulted largely from modifications in application only made possible by new equipment and fermenting room design. Electrification and the use of concrete for construction of fermenter tanks are the factors chiefly responsible for present

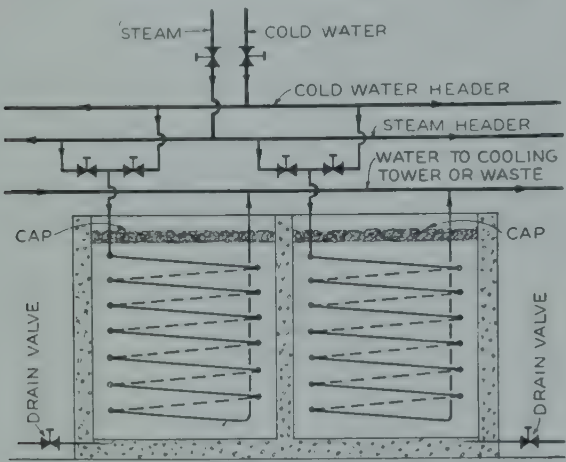


Fig. 2. Cooling Coils in Concrete Fermenters.

success of the method. Twice daily pumping-over is substituted for punching. Pumping is continued until all the excess heat of the cap is removed. The concrete construction permits permanent installation of the coils in the fermenter. They are mounted about one foot away from the side walls, and centrally positioned with respect to height of the side wall. Water which is either wasted or recirculated after passage over a cooling tower is allowed to flow continuously during the first 48 hr or until the must reaches 5 Balling.

Location of the coils in the fermenting tanks is a matter of compromise between good refrigeration practice and convenience of operation. In the wineries producing dessert wines this application is successfully made by positioning the coils as noted above, so as to be in contact with the fermenting liquid. The ebullition of the fermenting liquid produces reasonably efficient heat transfer. Soft drawn, 2-in. copper tubes, with center lines 10 to 12 in. vertically, are most frequently used. It is common practice to provide at least 1 lin ft of piping for each 100 gal of fermenter capacity.

One advantage of this system is tha the temperature of fermentation is nearl uniform throughout its whole course. Alsc cooling is on a 24-hr basis and the coolin operation is carried out with greate facility. Excessive oxidation as a resul of frequent pumping must be avoidec and this is accomplished by discharging th flow from the pump as a full stream fron the end of the hose rather than sprayin the discharge over the surface. Modifica tions of this system are also in use, incluc ing bulkheads and frameworks for keepin the cap submerged throughout fermenta tion, and cooling coils located in both th liquid above and below the framework.

The **externally located coolers** are use most commonly by wineries producing tab wines exclusively. Fermentations for th most part are on a smaller scale and a carried out in cylindrical wooden ferme ters rather than rectangular concrete fe menters. These and other factors make th system better suited to this type of oper tion. The units are principally single-pas water-cooled, counter-flow, shell-and-mul tube coolers, although plate type coolers a also coming into use. Both types of uni are operated on the counter-flow princip

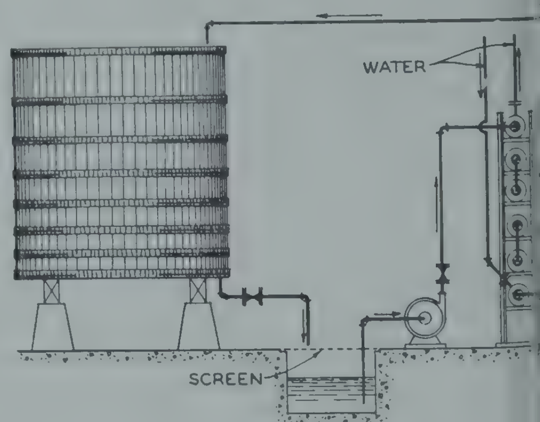


Fig. 3. Cooling Fermentations with External Shell-and-Multitube Cooler.

The shell-and-multitube units cons of several 20-ft lengths of 3 or 4- galvanized iron pipe, inside of which a mounted from three to seven ¾ or 1- thin-walled copper tubes, joined togetl by a system of return bends designed produce separate water and wine flo

ipports placed at intervals along the bes to prevent sagging assist in pro-ding turbulence of the water flow. The oling surface varies from 121 to 228 ft in the various makes of units. They e mounted either as a single or double ink of horizontal sections of pipe.

Plate type coolers have several ad-intages which insure wider future usage these units for cooling purposes. They e extremely flexible in operation and oling capacity and their high rate of eat transfer makes them unusually high-ficiency heat exchangers. They occupy tle space and are constructed of corro-on-resistant metals. The chief disad-intage in their use at present is that the ust has to be screened carefully to pre-ent seeds and skin particles from plugging e channels between the plates.

Performance studies conducted under tual winery conditions showed that eration of the units varied somewhat id was dependent largely upon the size the unit and location of the winery. he free-run wine, after screening to re-ove particles of skin and seeds, was umped through the cooling unit at rates rying from 1,000 to 3,000 gal per hr and as discharged over the cap in the manner eviously described. The water flow rough the units was found to vary from 00 to 5,000 gal per hr. The mean rate of eat transfer, from nearly 100 tests on rious units, was found to be 245 Btu er hr per sq ft cooling area per degree ean temperature difference. The range the rate of heat transfer in these tests aried from 111 to 390 Btu per hr per sq cooling area per degree mean tempera-re difference, for a unit in which a low olume of wine and water were passing to at for a unit in which 2,600 gal per hr wine were passing against 3,360 gal per of water, respectively. Most economical se of the cooling water results when wine id water flow through the unit are ap-roximately equal.

Chilling Requirements for Tartrate Removal

Newly made wine contains cream of tar-r (potassium bitartrate) considerably in cess of saturation. The excess of cream of tartar must be removed to avoid an undesirable deposition in bottled wine. It can be removed naturally by prolonged storage at cellar temperature or hastened by cold storage treatment at temperatures slightly above that producing congelation.

For the cooling of wine to precipitate cream of tartar, the lowest possible temperature is desirable. The **freezing point** of table wines (claret, zinfandel, burgundy, sauterne, riesling, chablis, etc.) is generally between 22 and 20 F, while dessert wines (sherry, port, muscatel, angelica, tokay, etc.) freeze at temperatures varying from 12 to 7 F. The specific gravity for table wines varies from 0.990 to 1.00, while the specific gravity for dessert wines varies from 0.985 to 1.03. Specific heat likewise varies with type of wine, and tests show it to vary from approximately 0.9 to 1.0. The chilling requirements for all types of wines are therefore usually calculated using a specific gravity of 1.03 and a specific heat of 0.9. The chilling load, however, is dependent not only upon these factors but also upon the amount of wine handled per unit time, the average cellar temperature and the system of chilling employed.

Cream of tartar is decreasingly soluble in increased concentration of alcohol or decreased temperature. Tests show, however, that merely chilling a wine to a temperature just above freezing is not sufficient to cause the separation of appreciable amounts of cream of tartar. To remove that portion in excess of the amount the wine will tolerate when bottled, the wine must be stored at the cool temperature for a period of time which depends upon the nature of the wine and the temperature of storage. Contrary to results that might be predicted from solubility data, the rate of precipitation from table wines is more rapid than from dessert wines at the same temperature. Likewise, the rate of precipitation from a white wine is faster than from a red wine. The above statements also hold for wines that are refrigerated and maintained in a completely congealed state. In general, both table and dessert wines should be held constantly at temperatures within a degree of their congealing temperatures for a period of 15 days or

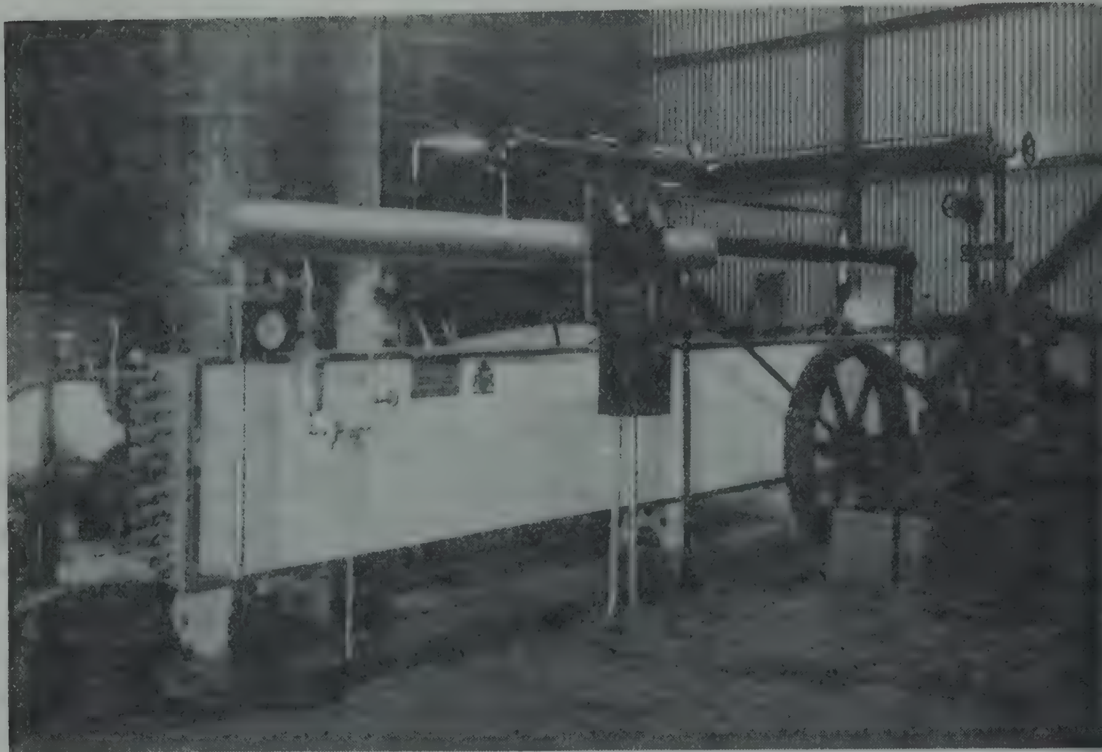


Fig. 4. Refrigerated Heat Interchanger for Chilling Wines.

more. If the wine is completely congealed, however, the same result can be accomplished in 3 to 4 days.

Methods of Chilling Wines

The methods of chilling wine can be divided into three classifications: (1) Those in which the chilling apparatus is mounted inside the chilling tank; (2) those in which the chilling apparatus is external to the chilling tank (**Fig. 4**); (3) those in which the chilling tanks are located in refrigerated rooms (**Fig. 5**). The refrigeration load differs considerably for each method as does also the method of operation required.

In the systems in which the **chilling apparatus is mounted in the tank,** the method of installation varies considerably. The units are usually mounted to the top of the tank but may be located centrally or at the sides with respect to the diameter of the tank. They may either consist of coils or plates, of finned construction for greater heat transfer. The tanks used vary from 2,000 to 5,000 gal in small installations to from 10,000 to 30,000 gal in the larger installations in the wineries producing dessert wines. In an average instal tion several tanks are fitted with coils, located centrally to the compressor sy tem. Wine from other parts of the stora cellar is pumped into one of the chilli tanks and the refrigerant allowed to e pand through a suitable valve until t entire contents of the tank are reduced the desired temperature. The refrigera is then shut off and the tank allowed to a sume cellar temperature.

There are several disadvantages in t above system. Seldom do the contents the tank cool uniformly, there being wi temperature differences between top a bottom of the tank. There is also a d tinct tendency for water to freeze out or the coils, particularly in those syste where a large temperature different exists between the refrigerant and t wine. Where this occurs the refrigerat capacity of the coils is greatly reduc Another disadvantage, one that can res in complete loss of the wine in cert cases, is that pipes or plates may leak a admit the refrigerant to the wine. main advantages are cheap construct costs and flexible operation.

This system is now considered obsolete. Nearly all the new and replacement installations put the chilling tanks in refrigerated storage rooms.

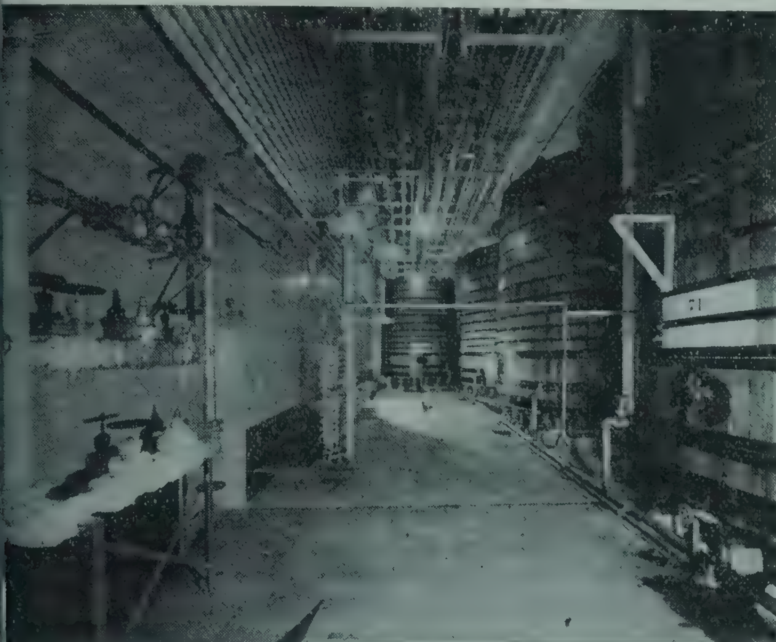


Fig. 5. Refrigeration Section of the Padre Vineyard Company Winery at Cucamonga, California. Chilling Wines for Deposition of Tartrates and Other Colloidal Materials.

The external chilling apparatus is usually single-pass, shell-and-multitube coolers, with the wine flow through the tubes and the refrigerant being expanded into the shell. In operation, the wine from a storage tank is circulated through the unit until it reaches the desired temperature. The system is completely satisfactory if sufficient refrigeration capacity is provided to chill the contents of the tank rapidly. The wine warms in storage more rapidly than is believed and frequently this factor has not been taken into consideration in the calculation of the refrigeration load. Because of this condition, the total refrigeration load is best split unevenly between two or more units. The larger unit is used for reducing the wine to chilling temperature, while the smaller unit is used to hold it at constant temperature for the required chilling period. Approximately 10 tons of mechanical refrigeration are required to hold 30,000 gal of wine at a constant 16 F.

Equipping the storage cellar with a refrigeration room of large capacity containing a considerable number of tanks is the most desirable method of chilling wines. As already indicated, the rate of precipitation of cream of tartar is a time-temperature relationship, the time necessary to effect adequate precipitation being markedly dependent upon the temperature. While a period of 15 days or more may be adequate for most wines held to within a degree of their congealing points, this time is markedly prolonged by a temperature rise of only a few degrees. This is one of the chief disadvantages of the previous two systems.

In operation the wine may be allowed to come to the temperature of the room through simple placement in storage. More frequently, however, the system is supplemented by use of an external chilling apparatus. The wine from the outside storage cellar is then chilled almost to refrigerated storage temperature by circulation through the shell-and-tube cooler. The wine is then held at constant temperature for the time required to effect adequate cream of tartar separation.

Shell-and-tube heat interchangers frequently become coated with a deposit of tartrate material which reduces their efficiency. This is easily removed by circulation of a dilute lye solution through the system. All systems should be constructed of non-corrodible metals and the refrigerant used should be non-injurious to the wine or health in case of leaks in the systems.

Refrigeration Requirements for Cooling Heated Must

Exposure of crushed red grapes (must) to temperatures of 190 F destroys the cel-

lular structure and liberates the red coloring matter into the juice. The change in physical structure also permits easy separation of juice and cellular materials by pressing. When heating and cooling cycles are carried out in heat transfer units designed for rapid heat exchange little or no change in flavor occurs. Red grapes can thus be fermented as juice and the pomace need never enter the fermenting cellar.

Present units are for the most part still experimental and are of the shell-in-tube type. They consist of 20 ft lengths of 4 inch pipe inside of which is mounted a single length of 3 inch pipe, connected by suitable return bends and banked together in a variety of ways. Several sections are used for heating, more for heat interchange and others for cooling. It now appears that reducing the crushed mass to much below 120 F with heat interchangers is impractical. Cooling from 120 F to 70 F or the removal of from 85,000 to 100,000 Btu per ton of grapes passed through the units must be provided. Very few wineries have the required amount of refrigeration to successfully complete the cycle. Water as a secondary refrigerant appears most adaptable to the process at the present time.

Future Trends

There has been little change in standard practice since this chapter was first written. However, as already noted, considerable change is in prospect. The fact that the method of color extraction by heat requires more refrigeration than most wineries now possess will not prove the deterrent to its adoption one might expect. Its advantages—complete color extraction, conversion of the grapes to juice instead of must, the elimination of the pomace handling within the fermenting cellar, an easily controlled uniform temperature of fermentation, automatically controlled to constant temperature if desired, etc.—far outweigh the economic disadvantages of additional required refrigeration. The exact nature of the new installations is still problematical but the entire refrigeration requirements of a winery should be engineered into a flexible, coordinated whole. Refrigeration appears destined to play a very important role in modern wine-growing.

If you searched this chapter for something which was not found in it, please let the editors know.

31. STORAGE OF CANNED FOODS

CANNED foods are not ordinarily stored under refrigeration. However, it is well known that storage at relatively high temperatures should be avoided and that storage at low temperatures results in longer life of the cans and better preservation of the contents. General instructions for the storage of canned foods call for a cool, dry storage room that does not get below freezing temperature.

Repeated experiments have confirmed commercial experience that prolonged storage at high temperature may result in loss of color and flavor of the canned food, as well as possible failure of the cans due to "pinholing" or the development of hydrogen gas pressure. In general, the rate at which these failures occur is a direct function of the temperature at which foods are stored. In the case of certain products, there is a slow chemical reaction between the contents of the can and any exposed metal on the inside of the can. The rate of this reaction varies greatly with individual products, but in general the rate also varies with the temperature according to the general laws governing chemical reactions.

Canned foods should not be subjected to freezing temperatures, although they are not rendered injurious by freezing, and even when frozen solid the cans seldom leak. After thawing the contents are still wholesome. Freezing, however, may cause some breakdown of the tissues, and, although in many products this is so slight as to be inconspicuous, with other foods there is a decided change in the texture or consistency of the product. There is no change in color or flavor because of freezing.

One of the difficulties encountered in the cool storage of canned foods is the danger of **sweating** of the cans with subsequent rusting and perforation. If cool cans are exposed to relatively moist warmer air, the moisture condenses on the can and may result in severe rusting. Because of this danger of sweating, storage rooms with canned foods should be kept from sudden changes in temperature or humidity. In the ordinary storage of canned foods it is commercial practice to keep the doors and windows closed when the relative humidity is high and to open them when the relative humidity is low so that the moisture in the air may be kept at a minimum. In warehouses not equipped for close control of temperature, it is to be expected that the temperature of the stored goods will follow, with some lag, the general seasonal fluctuations of outdoor temperature. Under these circumstances, the greatest danger of sweating exists when the outside temperature is increasing, and successful control depends on keeping the temperature lag to a minimum without undue exposure to air of high humidity.

In some instances cans bearing labels show severe staining of the labels if sweating occurs.

It should be borne in mind that although conditions within the storage warehouse may be such that sweating does not occur during storage, if the cans are brought out suddenly from the cold room to a warm

HOWARD R. SMITH, Author Chapter 31. Educated at Case School of Applied Science, BS, 1912. Formerly with Bureau of Chemistry, USDA, 1912; Food and Drug Administration until 1929, Research Laboratory Natl. Canners Assn., 1929 to date; participated in studies with the Transportation Division of conditions obtaining in the shipment of canned foods, especially during the winter months; collaborated in the publication of an article on "Effect of Freezing on the Quality of Canned Foods," *Food Research;* during the war took part in study of special protective coatings to be put on canned foods to prolong their life during the severe conditions encountered in supplying canned foods to the armed forces.

At present with the Research Laboratories, National Canners Assn., Washington, D.C.

humid atmosphere the resulting sweating may be sufficient to cause damage that may be attributed to the storage conditions.

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If you searched this chapter for something which was not found in it, please let the editors know.

32. REFRIGERATED STORAGE OF DEHYDRATED ANIMAL PRODUCTS

DEHYDRATED foods permit the conservation of manpower, packaging materials, and shipping space, and in some instances they may be stored for short periods at moderate temperatures without refrigeration. In addition, dehydration permits conservation of surplus foodstuffs for use in off seasons. Much work has been done on determining their perishability, and it has been found that refrigerated storage is necessary for some dried foods, if storage for long periods is desired.

Dried Egg Powder

Effect of storage temperature. At ambient temperatures, dried whole egg powder is much more perishable than was formerly believed **(Table 1)** and refrigeration to at least 60 F is recommended.[34] At lower temperatures the powder keeps much better.[29] It is interesting to note that, by sensitive objective measures of quality,[20,21,28] egg powders slowly deteriorate even at temperatures as low as −40 F, as shown by **Table 2.**

Estimates of the storage life of dried whole egg powder of 4 to 5 percent moisture content, based on the foregoing work, are given in **Table 3.** These are conservative estimates of the lengths of time during which the stored product can be considered of first quality, suitable for the preparation of a table dish such as scrambled eggs. For manufacturing purposes the powder lasts much longer, the storage life being approximately doubled. Lowering the moisture content also lengthens the storage life.[29,33] Packing in CO_2 **(Table 4)** was mildly beneficial.[29,34] While many attempts are being made to render egg powder used for baking less perishable, e.g., by the addition of sugar or sodium bicarbonate to the liquid egg before drying,[22] to date refrigeration has been found necessary for the preservation of dried whole egg powder suitable for table use as scrambled eggs. **Table 5** has been reproduced from an excellent article by Elsie H. Dawson et al,[8] and is in general agreement with the estimates given in Table 3. The necessity of refrigeration for stored dried egg is obvious.

Sugar-egg powder, a dehydrated mixture containing two parts egg solids and one part sugar, is a promising replacement for the frozen egg used in the bakery trade. Sugar-egg has storage characteristics very similar to those of plain egg powder,[10] but it has a slightly longer storage life. Figure 1 shows that reducing the storage temperature prolongs the time in which Grade A sugar-egg powder will retain its quality according to Canadian grading criteria.[4]

MELVILLE WILLIAM THISTLE, Co-author Chapter 32. Born 1914 in St. John's, Newfoundland. Educated at Mount Allison University, BS, 1936; MA, 1938. Formerly, Instructor at Mt. Allison University 1937–38, and during the same period was on loan to the Government of New Brunswick in connection with the economic brief for the Rowell Commission.

Author of fifty scientific and technical articles, mainly on food preservation; co-author Chapter 30, 1946 Applications Volume, ASRE Data Books.

At present, Biochemist, Division of Applied Biology, National Research Laboratories, Ottawa, Canada, 1938 to date.

JESSE ARTHUR PEARCE, Co-author Chapter 32. Born 1914 in Regina, Saskatchewan, Canada. Educated at Queen's University, BA, 1938; MA, 1939; McGill University, PhD 1941. Formerly, public school teacher, 1933–36; research assistant at Queen's University, summers 1937–39; McGill University, summer, 1940.

Author of seventy scientific and technical articles, mainly on problems of food preservation; co-author Chapter 30, 1946 Applications Volume, ASRE Data Books.

At present with the Division of Applied Biology, National Research Laboratories, Ottawa, Canada, 1941 to date.

WILLIAM HARRISON COOK, Co-author Chapter 32. Born 1903, in Alnwick, Northumberland, England. Educated at the University of Alberta, BS, 1926; MS, 1928; Stanford University, PhD, 1931; University of Saskatchewan, LLD, 1948. Formerly, Assistant Plant Biochemist at the University of Alberta 1926–30; Associate Research Biologist at the National Research Council of Canada 1930–41.

Author of one-hundred scientific and technical articles, mainly on proteins, food preservation, and refrigeration; co-author Chapter 30, 1946 Applications Volume, ASRE Data Books.

Officer of the Order of the British Empire 1946; Fellow of the Royal Society of Canada 1943; Fellow of the Agricultural Institute of Canada 1947.

At present, Director of the Council's Division of Applied Biology, 1941 to date.

Powdered egg yolk shows storage characteristics similar to those of dried whole egg powder; **Table 6** is reproduced from work done at the University of Illinois.[30]

Effect of moisture content. Egg powder is generally dried to about 4 percent moisture in a single-stage drying process, although lower moisture contents can be attained. Reducing the moisture content to 2 percent or less approximately doubles the useful life of the product.[29,33] Atmospheric conditions under which either sorption of water or condensation may occur are dangerous,[3] since egg powder as currently manufactured is hygroscopic at relative humidities higher than 30 percent, and hence must be protected from moisture uptake. Reasonable protection of powders of 4 percent moisture content is provided by flexible containers developed during the war emergency,[37] but powders of very low moisture content may require a rigid container to maintain the moisture content at a low level.

Table 1. Quality of Dried Egg Powders Stored for Various Periods at 45, 60, and 75 F

Time, months	Temperature, F		
	45	60	75
Fluorescence values			
1	26	27	29
2	24	25	31
4	29	30	33
6	31	36	42
Potassium chloride values			
1	72	67	71
2	71	71	62
4	61	58	44
6	62	58	42

Bacterial content. Bacterial mortality increases with increasing time and temperature.[9] At 45 F and lower the majority of organisms survived eight months' storage. Up to 8.6 percent, moisture content had little effect on bacterial survival. At moisture levels above 5 percent there was an increase in the number of molds, particularly at 75 and 98 F. In another study, salmonella organisms survived for 37 weeks at temperatures of −11, 36, and 68 F, but were all killed after 28 weeks at 86 F, 8 weeks at 99 F, and 8 weeks at 113 F, i.e., these organisms survived under the temperature conditions necessary for maintaining quality in the powder.[37] The bacterial content of egg

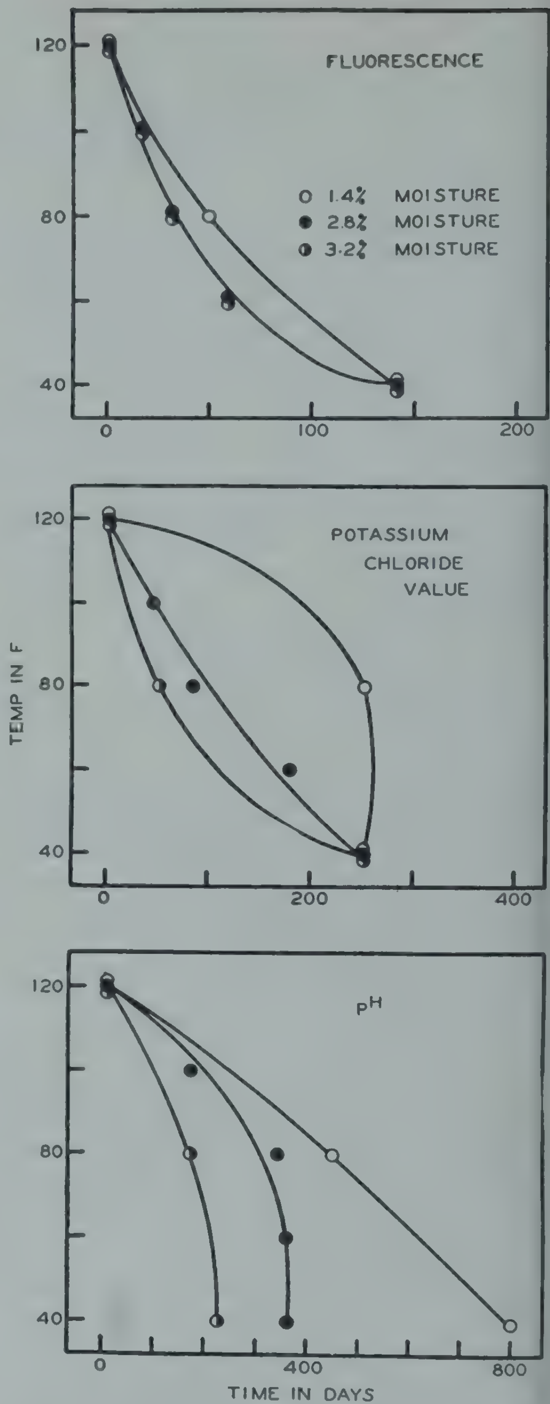

Fig. 1. Storage Life of Sugar Egg Powder.

Table 2. Quality Changes in Whole Egg Powder Stored at Low Temperatures

Measurement	Storage temperature, F	Storage period, months					Replicate error
		Initial	1	2	4	8	
Potassium chloride value, percent	−40	70	70	67	69	63	2
	0	68	70	70	70	62	
	40	68	69	67	69	55	
Fluorescence, units	−40	15.0	17.0	17.8	17.9	20.6	0.5
	0	15.2	16.9	17.6	18.1	21.8	
	40	15.0	16.6	18.4	19.0	24.5	
Palatability ratings	−40	7.7	7.9	8.0	7.8	8.2	0.7
	0	7.6	7.9	8.0	—	8.3	
	40	7.6	8.0	7.3	8.3	8.7	

powder is not regarded as a serious problem, but manufacture and handling must be done under sanitary conditions.

Vitamin stability. Work at the Western Regional Research Laboratory, U.S.D.A.[13] showed the following: Spray drying of whole eggs had no significant destructive action on the vitamin content in the eggs —namely, vitamin A, vitamin D, thiamin, riboflavin, pantothenic and nicotinic acids. Vitamin A was found to be unstable during storage of dehydrated eggs; after nine months 60 percent was lost at 15 F, 75 percent at 70 F, and 80 percent at 98.6 F. Pantothenic and nicotinic acids were quite stable under these conditions.

Only slight destruction of riboflavin occurred during nine months at 98.6 F and essentially none at lower temperatures. Thiamin was stable at 15 F for nine months; during the same period the losses were 46 per cent at 70 F and 50 percent at 98.6 F.

In a later study vitamin A retention in dried eggs stored for 6 months in a loose pack was as follows:

Temp, F	*Vitamin A retention, %*
32	80
50	74
68	69
100	30

Compressing the powder effected no improvement, and packing in tin cans doubled retention only at 100 F.[2] In still another study storage of egg powders at 98 F for 9 months resulted in a loss of practically all the thiamin, but during storage for the same period at −40 F only about 8 percent of the thiamin was lost. Riboflavin and nicotinic acid were not affected by storage at either temperature.[5]

Dried Milk

In a study of effects of processing factors on keeping quality, it was found that dried whole milk powder from concentrated milk pre-heated to 170 F for 30 min, or to 180 F for 10 min, decreased very little in flavor during storage at 45 F; powder from concentrated milk pre-heated to 170 F for 10 min showed a definite decrease; and powder from concentrated milk pre-heated to 160 F for 30 min showed marked decreases in flavor. Powder stored at 100 F showed little difference in keeping quality regardless of the pre-heating conditions.[15] The high temperature treatment (180 F) caused a more rapid decrease in solubility when the resulting powder was held at 100 F but no decrease in solubility was observed in samples held at 45 F.[16]

Temperature is probably the most important factor affecting the quality of stored milk powder. The digestibility of spray-dried powders decreased 3.3 percent and drum-dried powders decreased 6.3 percent, during storage for four weeks at room temperature.[17] The development of tallowiness appears to be the most important form of deterioration; time for the development of tallowiness has been determined by organoleptic tests on powders stored at 32, 51, and 77 F for 18, 12 to 13, and five to six months respectively.[27]

Table 3. Estimated Storage Life of Dried Egg Powder of 4 to 5 Percent Moisture, for Use as an Egg Dish

Storage temperature, F	Storage time, months
90	½
60	3
45	6
32	12

Other investigators found that tallowiness developed in three months at 68 F.[6] Tallowy odor showed regular increases as the storage temperature was increased from 32 to 98 F.[12]

However, much of the difficulty has been removed by packing in an inert gas, which was reasonably effective in retarding or preventing the development of tallowiness in milk powder.[14] Gas-packed, roller-dried, full-cream powders, after storage for several years at 59 F, were as palatable as fresh samples. Although gas packing does not completely eliminate deterioration, it does reduce spoilage to negligible proportions over very long storage periods.[14] Peroxidase activity in the milk powders can be preserved for one year during storage at 45 F provided that the powder is packed in a minimum of air at low moisture content.[17] The beneficial effect of packing dried whole milk powder in an inert atmosphere was less marked in samples held for one year at 35 F than in samples held for one year at 100 F.[14]

Dried Meat

Dehydrated beef, pork, mutton, and lamb have excellent keeping quality when stored in cans at moderately low temperatures. After two to four weeks' storage at 110 and 135 F, samples developed a flavor resembling that of cured meat and the color became a marked red. Samples at 135 F developed a scorched flavor in six months, while samples at 110 F developed an overcooked flavor in 11 to 12 months. Samples stored at room temperature and lower showed little change in flavor or color in 12 months.[31]

Dehydrated pork and beef packed in cans under air, nitrogen or vacuum were still edible after six months' storage at 135 F and after one year's storage at 110 F, room temperature, and 36 to 38 F.[35] Dried chicken stored in quart sealers kept for about four months at 75 F.[18]

In dried cured beef, stored in the presence of air, oxidative rancidity developed much more rapidly than in normal dried meat.[1] Dried cured beef with 4 percent moisture content deteriorated at −4, 32, 68, and 98.6 F in about two weeks. Oxidation was favored by dry conditions and was inhibited as the water content of the meat increased, except at the lowest storage temperature. In the absence of air the materials kept in fair condition for 10 weeks.

Dried pork stored for a year in cans at 75 and 98 F showed no change in palatability.[19] Storage behavior of dried pork stored in paper-bodied containers is shown in Table 7. Keeping quality was no better at the freezing point than at room temperature, but some deterioration occurred at the intermediate temperature of 60 F. This curious behavior was also noted during storage studies on dehydrated mutton.[32] Storage of dehydrated pork for 168 days at 0, 70, and 110 F had no material effect on the digestibility of the pork fat but reduced the biological value of the protein.[11]

Vitamin stability. Preliminary data on

Table 4. Effect of Various Methods of Packing on the Fluorescence Values of Dried Egg Powder Stored at 75 F

Storage period, months	Method of packing				
	Air	Vacuum	Carbon dioxide	Nitrogen	Compressed tablet
1	26	28	26	29	29
2	29	32	25	31	29
6	44	61	39	46	42

able 5. Approximate Number of Weeks that Dried Whole Egg with 3 to 5 Percent Moisture Can Be Stored at Various Temperatures for Subsequent Use in Five Food Products

roduct in which ried egg is used	Storage temperature, F					
	32	45	68	75	86	110
:rambled eggs	52	52	12	9	2	1
aked custard	52	52	40	20	5	1
opovers	52	52	40	21	7	2
(ayonnaise	52	52	52	31	7	2
oundation cake	52	52	52	40	12	2

ehydrated pork and beef indicated that here is appreciable loss of thiamin during ne to two months' storage at 80 F, and seere losses at higher temperatures. A few asays also indicated little or no loss of iacin, riboflavin, or pantothenic acid even uring storage for several months at temeratures as high as 140 F.[26] Thiamin reained in dried pork after 21 days' storage t various temperatures was as follows:[25]

Temp, F	*Thiamin retention, %*
20.2	100
37.4	96
80.6	77
98.6	43
120.2	0
145.4	0

In another study, 36 weeks' storage of dehydrated pork resulted in 70 to 80 per-

Table 6. Analysis of Samples of Powdered Egg Yolk after Periods of Storage at Different Temperatures

Sample A						
Storage temperature, F	Storage time, weeks	pH	Insoluble material, ml	Total bacteria per gram	Flavor	Color
5–20	Initial	6.50	4.5	420	Very good	Golden yellow
	6	6.50	4.5	400	Good	Golden yellow
	12	6.28	7.6	600	Good	Golden yellow
	24	6.02	7.6	700	Good	Golden yellow
	36	6.15	9.0	1000	Good	Golden yellow
	52	5.79	7.5	2100	Good	Golden yellow
	72	6.31	8.0	1500	Good	Golden yellow
40	6	6.40	5.0	480	Good	Golden yellow
	12	6.20	8.5	300	Good	Yellow
	24	6.05	8.5	1300	Good	Slightly discolored
	36	6.15	9.0	1100	Good	Slightly discolored
	52	6.27	8.5	900	Fair	Slightly discolored
	72	6.25	9.5	400	Fair	Slightly discolored
70	6	6.35	5.0	200	Good	Yellow
	12	6.08	8.8	300	Fair	Yellow
	24	5.87	8.8	500	Fair	Definitely discolored
	36	5.91	9.0	300	Stale	Brown
	52	5.87	9.0	100	Stale	Brown
	72	5.90	13.0	200	Stale	Brown
90	6	6.26	8.0	200	Slightly bitter	Yellow
	12	5.95	8.5	100	Stale	Dead yellow
	24	5.80	9.5	700	Very stale	Definitely discolored
	36	5.81	9.5	200	Very stale	Brown
	52	5.86	8.5	500	Very stale	Brown
	72	5.80	12.5	0	Very stale	Brown

Table 7. Palatability Scores for Dehydrated Pork After Storage for 12 Months in Paper-Bodied Containers
(Initial palatability, 6.6)

Storage temperature, F	Palatability score	
	6.5% moisture	14% moisture
98	3.0	2.7
75	4.1	—
60	3.2	2.9
32	4.2	3.9
0	5.5	5.2

cent retention of nicotinic acid at all of the following storage temperatures: 0, 70, 110 F, but 72 percent of the thiamin was retained during storage at 0 F, 26 percent at 70 F, and only 0.1 percent at 110 F.[24]

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33. REFRIGERATED STORAGE OF DEHYDRATED FRUITS AND VEGETABLES

DEHYDRATED fruits and vegetables differ from each other in certain important characteristics. Fruits contain high percentages of sugar and are dehydrated to moderately low moisture contents, in the range of 15 to 25%. In contrast to fruits, vegetables are dried to relatively low moisture levels (under 8%). An exception is the "nugget" type of dried fruit, which is an ordinary dried fruit, ground or chopped into very small pieces and re-dried under vacuum to a moisture content of approximately 2%. White potato granules are also reduced to small piece sizes and dried to a low moisture content (8–10%). The higher acidity and sugar content of fruits provide an adverse physical environment for bacteria, and thus makes their growth impossible even though the moisture level is high as compared with dehydrated vegetables.

The dried fruit industry is large and well established. Dried vegetables, however, are predominantly associated with military operations and were very important during World War II. An exception is the dehydration of condiment or flavoring vegetables such as garlic, onions and parsley, which has been well established though a comparatively small industry over a long period. Dehydrated soups are also a well established minor industry and contain not only flavor and condiment vegetables, but other dried vegetables also, as well as other constituents. Since the recent war the use of dehydrated vegetables has increased, not only in soup mixes, but in canned hash, soups and stews. Mashed potato powders or granules (a new product) yield mashed potatoes when simply added to hot water and milk and whipped about one minute.

In recent years research has established with reasonable clarity, the relationships of high quality in dried fruits to low temperatures in storage. Research on dried vegetables, on the other hand, has followed chiefly the military objective which is to develop products, packages, package atmospheres, and special treatments that will yield products adapted to the severities of military use.

Some of the new directions of research involving dehydration are of interest. Dehydrofreezing (drying to a reduction of about 50% in weight and volume, followed by freezing) has yielded excellent experimental products, both fruit and vegetable.[4] Concentration of juices by low-temperature evaporation and preservation of the concentrate by freezing (see chapter 12) is essentially a dehydrofreezing process, which has succeeded on a large scale in recent years. Methods of drying (in heated flowing air, under vacuum, and freeze-drying) are also under consideration. Packaging under nitrogen or carbon dioxide and in the presence of a desiccant to achieve further reduction in moisture content has been evaluated at least partially for dehy-

HELMUT CHARLES DIEHL, Author Chapter 33. Born 6/6/94, in Bridgeport, Conn. Educated at Michigan State College, BS, 1918; Johns Hopkins University, 1919–20; University of Maryland, 1923–24; State College of Washington, 1938–39. Formerly with the Chemical Warfare Service, Med. Div., Yale, 1918; U. S. Dept. of Agriculture, 1920; Physiologist in charge of U. S. Hort. Field Lab., Wenatchee, Wash., and Yakima, Wash., 1924–31; Sr. Physiologist in charge U. S. Frozen Pack Lab. Seattle, Wash., 1935–40; U. S. Fruit and Vegetable Products Lab., Pullman, Wash., 1935–40; Senior Chemist and Chief, Commodity Processing Div., Western Regional Research Lab. Albany, Calif., 1940–43; Senior Chemist in Charge Dehyd. Training Schools, USDA, 1942; Consultant, Western Reg. Research Lab., Albany, Calif., 1948 to date; Director and Secretary, Refrigeration Research Foundation, Berkeley, Calif., 1944 to date.

Author of reports and bulletins on maturity, harvesting, handling and storage of fruits and vegetables, especially with freezing preservation of these products.

Fellow, Amer. Assn. Adv. of Science; Amer. Inst. of Chemists; Amer. Public Health Assn.; Member, Amer. Soc. of Refrig. Engrs.; Natl. Assn. Prac. Refrig. Engrs.; Charter member and President, Institute of Food Technologists; Member, Amer. Soc. Hort. Science; Catholic Round Table of Science; Catholic Comm. for Intellectual and Cultural Affairs; Engineers Club of San Francisco; Rotary International, Berkeley, Calif.; Sigma Xi; Xi Sigma Pi.

drated vegetables. Treatment with sulfite to retain color and extend storage life has been used widely for dried vegetables, and recently application of a light coating of laundry starch to diced carrots prior to dehydration has achieved excellent results in retention of color and other quality factors during storage in cellophane at 84 F without sulfite.[7]

Production Data

Dried fruits—Dried fruits are important in volume, as indicated by the following production data (dry basis) for recent years:

1941	489,195 tons
1942	536,780 tons
1943	701,270 tons
1944	594,580 tons
1945	566,000 tons
1946	534,500 tons
1947	615,585 tons

Of these totals, raisins often account for 50 percent or more in many years, although raisin production varies annually over a wide range. Prunes account for approximately a third. Others, in declining order of approximate tonnages, are figs, peaches, apples, apricots, dates and pears.[11]

Dehydrated vegetables—These products reached an all-time high point in 1944–45 when a largely war-created industry produced over 100,000 tons. Of the vegetables dehydrated, white potatoes accounted for over two-thirds of the total amount. Others dehydrated were sweet potatoes, carrots, onions, cabbage, beets, garlic, tomatoes, rutabagas and turnips, celery and greens. Over 200,000 tons of dehydrated soups and stews were produced in that year.

With the end of the war the government largely ceased purchases and the vegetable dehydration industry declined. Total exports of dehydrated vegetables were, however, 25,843,000 pounds in 1946–47, the latest year for which statistics are available, and exports of dehydrated soups amounted to 68,358,000 pounds in the same year.[11]

Low-Temperature Relationships

For dried products that are not sealed in an atmosphere other than air, refrigerated storage at 40–50 F or lower retards and controls insect infestation. Substantial killing occurs with exposure at 32 F for 6 months or longer. A temperature of 0 F kills insects within a few hours.[2] An alternative method is fumigation which is used considerably in commercial practice.

Nonenzymatic browning in dehydrated vegetables, that is, browning in products that have been scalded or blanched adequately to inactivate enzymes, is reduced in rate at low temperature. Cool storage offers protection for several years.[5,6]

Staling ("charred" or "off" flavor) and other deteriorative changes in dehydrated vegetables are inhibited by packing in nitrogen. In air-packed samples, however, the rate of staling is reduced at low temperature.[3]

It has been shown for dried apricots that increasing the temperature accelerates oxygen consumption, carbon dioxide production, disappearance of sulfur dioxide, and darkening.[10]

Molds and yeasts will grow slowly and cause deterioration of dried fruits at 40 F unless relative humidity is very low (below approximately 50%). At 32 F relative humidity is less important than at higher temperature.[9]

Dried Fruit Storage

The following recommendations are based on research conducted by the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture at Fresno, California. This summary constitutes recommendations for the storage of dried fruits.[1,2,8] A similar summary is included in U. S. Dept. of Agriculture Circular No. 278.[9]

General recommendations. The best storage conditions for the dried fruits listed below (except dates) are 32 F and 55% relative humidity. A storage temperature of 32 F is superior to 40 F or higher temperature in preventing browning, in retaining sulfur dioxide, ascorbic acid and carotene, and in giving insect control. Dates

should be stored at 28 to 32 F for short periods (a few months) and at lower temperatures for longer periods.

Specific considerations. For various dried fruits the following recommendations are pertinent:

Raisins. At 32 and 40 F, sugaring is prevented for well over a year at low relative humidity, provided the moisture content of the dried fruit is not unusually high. Keeping raisins in an atmosphere of low moisture content is important; for purposes other than insect control, low humidity is more important than low temperatures. Raisins usually contain 15 to 20% moisture; for extremely long storage a lower moisture content would be an advantage.

Figs. At 32 and 40 with low relative humidity, figs keep well for more than a year. At 55 F and higher temperatures they may darken within 5 months. Low humidity controls sugaring.

Prunes. At 32 and 40 with low humidity (about 55%) prunes keep well for over a year, in excellent condition. For storage of 4 to 5 months a moderate humidity (about 75–80%) is not objectionable.

Apples. At 32 and 40 with low humidity excellent color and texture are retained for a long storage period. A relative humidity of 75–80% is not objectionable at 32 but at 40 enough moisture may be gained to cause the fruit to mold within 8 months. During a period of 8 months 55 F may result in only slight browning, but considerable mold is probable, because of high humidity (85%).

Pears. Results are best at 32 and 40 with low humidity. At 55° there may be slight darkening during long storage.

Peaches. With sun-dried freestone peaches, results are best at 32 F with low to moderate relative humidity. At 40 F with moderate humidity, moisture pickup is too great. A temperature of 55 F permits darkening.

Clingstone peaches (dehydrated after steam scalding) withstand higher humidity than the freestone fruits at comparable temperatures. Otherwise they behave similarly to freestones.

Apricots. At 32 F with either low or moderate humidity, dried apricots remain in excellent condition. At 40 F with moderate humidity there is enough gain in moisture content to be somewhat objectionable.

Dates (sucrose or hard type, chiefly Deglet Noor). If well cured will keep until March at 28–32 F and for a year at 24 to 26 F. Usually they can be most conveniently stored at 0 F, and if very mature they should be stored at 0 F to prevent syrupiness. Uncured dates should be stored at 0 F to 10 F.[1]

Dates (soft or invert-sugar types). If well cured can be kept until Christmas season at 28 to 32 F, but if stored longer should be held at 15 F or lower. Zero to 10 F is convenient and beneficial. Uncured dates should be stored at 0 to 10 F.[1]

Dried Vegetable Storage

No specific recommendations of storage temperatures for dehydrated vegetables are available. Increase in storage temperature accelerates deterioration. The range in which this deterioration becomes rapid is above cool temperatures (50–65 F). Cool or air-conditioned storage is needed only for long periods. If insect control is desired, refrigerated or cold storage at 45 F or below is required. Products with higher than usual moisture contents can be expected to benefit by refrigerated warehousing, but in general the present aim in dehydration of vegetables is to lower moisture content to the point of stability without refrigeration. The question whether better products can be obtained economically with higher moisture content and possibly with less heat damage and better color and flavor, with refrigerated storage, has not been fully determined.

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34. BOTTLING OF CARBONATED BEVERAGES

IN THE manufacture of bottled carbonated beverages, it has been found desirable to cool the water used to a constant low temperature. This is done (1) to gain stability of the carbonated water during bottle filling, (2) to promote uniformity of the finished beverage, and (3) to permit reducing the pressure at which the beverage is filled.

In order to prepare carbonated water that will show the desired sparkle and release of carbon dioxide gas when the finished beverage is served, the water is supersaturated by using carbon dioxide under pressure in an apparatus known as **a carbonator.** The amount of gas dissolved varies directly with (1) the temperature of the water, and (2) the carbon dioxide gas pressure. It is found that the lower the temperature of the water, the less the gas pressure needed for a given carbonation of the water, for cold carbonated water shows less tendency to lose its gas while going through the bottle filling machines. That is, it is more stable.

The commonly used data on the relationship of pressure and temperature to the volumes of carbon dioxide dissolved per volume of water are presented in **Table 1.** Beverages of low carbonation fall below 3.5 volumes of carbon dioxide per volume of water, while the higher carbonation may run up to 4.5 volumes, depending on the product.

Table 1. Volume of CO_2 Gas Absorbed in One Volume of Water

Temperature, F	Pressure, in bottle, lb per sq in g										
	0	10	20	30	40	50	60	70	80	90	100
32	1.71	2.9	4.0	5.2	6.3	7.4	8.6	9.7	10.9	12.2	13.4
40	1.45	2.4	3.4	4.3	5.3	6.3	7.3	8.3	9.2	10.3	11.3
50	1.19	2.0	2.8	3.6	4.4	5.2	6.0	6.8	7.6	8.5	9.5
60	1.00	1.7	2.3	3.0	3.7	4.3	5.0	5.7	6.3	7.1	7.8
70	.85	1.4	2.0	2.5	3.1	3.7	4.2	4.8	5.4	6.1	6.6
80	.73	1.2	1.7	2.2	2.7	3.2	3.6	4.1	4.6	5.2	5.7
90	.63	1.0	1.5	1.9	2.3	2.7	3.2	3.6	4.0	4.5	4.9
100	.56	.9	1.3	1.7	2.0	2.4	2.8	3.2	3.5	3.9	4.3

JOHN M. SHARF, Author Chapter 34. Born 10/12/10, in Richfield, Utah. Educated at Iowa State College, BS, 1931; PhD, 1937; International exchange student Technische Hochschule, Karlsruhe, Germany 1933–34; University of London, Ramsay Laboratory of Chem. Engrg., 1934–35. Formerly, Technical Service Director, Amer. Bottlers of Carbonated Beverages, Washington, D.C., 1935–42; Research Laboratories, Armstrong Cork Co., Lancaster, Pa., 1942 to date.

Author of numerous articles in technical and trade publications. Has participated in food processing studies of National Canners Assn.; contributor to Amer. Public Health Assn. "Standard Methods for Microbiological Examination of Foods."

Member of Inst. of Chem. Engrs.; Soc. of Amer. Bacteriologists; Inst. of Food Technologists; Fellow Amer. Public Health Assoc.

At present, Chief of Closure Research, Research Laboratories, Armstrong Cork Co., Lancaster, Pa., 1942 to date.

Types of Water Coolers

The cooling of water with respect to other processes of water treatment is indicated in **Fig. 1.** This cooling step is carried out in one of a number of water cooling units of several designs:

1. Baudelot
2. Tank unit
3. Cascade tray
4. Shell-and-coil
5. Shell-and-tube
6. Carbonator-cooler.

The **Baudelot** or descending film type of

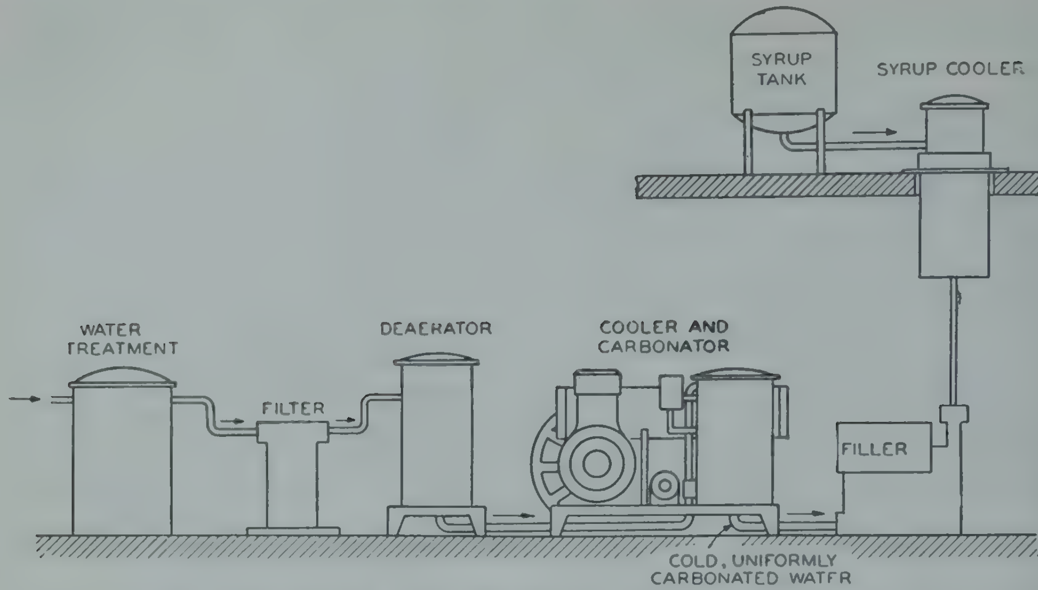

Fig. 1. Apparatus for Water Treatment and Cooling in Bottling Plant.

cooler consists of a series of refrigerant expansion coils over which the water descends by gravity, from a distributor at the top of the system.

The **tank** type cooler has the refrigerant expansion coils immersed in a tank of water as in **Fig. 2.** Other arrangements baffle the water for long flow.

The **cascade tray** type has a series of inclined trays in which the expansion coils are laid, over which the water passes in flowing by gravity from the highest tray on down to the lowest, usually in a zig-zag path. The internal-coil or **shell-and-coil** type of unit is usually described in the beverage business as a **closed system** cooler. Water goes through a closed pipe coil immersed in the refrigerant. This form of cooler, since it will operate under pressure, can also be used to cool water further after it has been carbonated.

All of the above types of coolers have **direct expansion** or direct heat interchange between the evaporating refrigerant and the water to be cooled. Differing from these is the **brine circulation** system which is used either for special design or as precaution against the possibility of refrigerant leakage into the water. In some plants this system has been adapted to brine already cooled in some other part of the plant for another purpose. Then the sam refrigeration system may be used for mor than one unit. The water being cooled i generally led through a closed pipe im mersed in the circulating brine.

Recently there have been ingeniou combinations made of the cooling surface built directly into the **carbonator units** Here the surfaces over which the water i run present a large area to the carbo dioxide atmosphere. The surface is cooled thereby doing double service. These de signs are, at present, variations of th descending film type of cooler as i **Fig. 3.**

These coolers are nearly all of special de sign whose capacity for cooling water based on previous performance, is know and specified by the manufacturer. Hence the capacity of cooling surface or units i best based on manufacturers' listing.

In large installations **shell-and-tube** ap paratus is used for chilling water. Specia problems have arisen in this field since th introduction of Freon-12 as a refrigerant commonly used in plants furnishing larg quantities of water, such as air condition ing systems. This cooler has found use i cooling water in beverage and other plants and in supplying **drinking water.** Th significant change from the design of othe

shell-type coolers is the number and size of passages for the introduction and removal of the refrigerant from the shell.

Still another type of water cooler is the U-type, having a series of pipes carrying the refrigerant, immersed in a shell containing water. The pipes are bent in U-form horizontally, to provide a smooth passage for the Freon.

Sanitation

In all of these types the factor of prime importance is keeping the water free from contamination, either with foreign substance or organisms picked up from the unit or from metals dissolved in transit. For these reasons, the units are designed for ease of cleaning, freedom from water stagnation, and built of corrosion-resisting non-toxic metal (preferably tinned or of resistant base metal such as stainless steel).

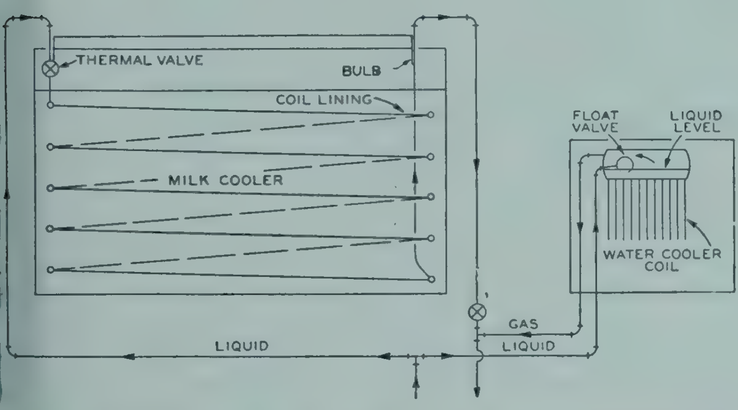

Fig. 2. Submerged Coils for Water Cooling. Self-Contained Low Side with Float Is Also Shown.

Cleaning is necessary to prevent any possibility of growth of organisms in the unit which would tend to contaminate the water passing through it. Water stagnation should be prevented for the same reason. Likewise, if a small amount of water is contained in the unit at any time, due to small reservoir tanks or pumps, the unit can be more readily drained and cleaned.

The smaller units for cooling can usually be set up in any place desired in the plant, while the larger units for plants of greater capacity may actually be built into a refrigerator room. With these smaller units the water being cooled should be protected from contamination by having a cover over the cooling surfaces and reservoirs. This prevents air circulation from the outside or accidental contaminatior by workmen, insects or dust. Wherever possible, all parts should be of metal, for wherever wood or organic material is in contact with the water there is greater possibility for growth of microorganisms. With the units built in a refrigerator room, the same precautions should be observed and, if it is desirable to demonstrate this room in plant tours, **inspection windows** should be provided rather than allowing visitors to enter the room. It has been found wise in a number of instances to keep the coolers locked to prevent tampering.

The refrigerants commonly used in these units vary with the design and size and may be ammonia, Freon, methyl chloride, or less often sulfur dioxide, carbon dioxide or others. The types of compressors vary also with the particular unit in question, and, as with other commercial units beginning at several tons' capacity, they vary from the small high speed units on to the larger heavy duty units.

Few of the installations, because of the installation cost, use spray ponds or towers for cooling condenser water; most rely on main or well water. Increased economy can be gained by employing used or warmed condenser water for some manufacturing processes such as rinsing jets on the bottle washing machines. Care must be taken that this water is in no way contaminated with grease, oil or other substance which might in any way interfere with the cleanliness of the bottle.

Water Temperatures

The temperature to which water must be cooled depends on the type of bottle filling machinery used. They may be divided into three general classes: (a) Those

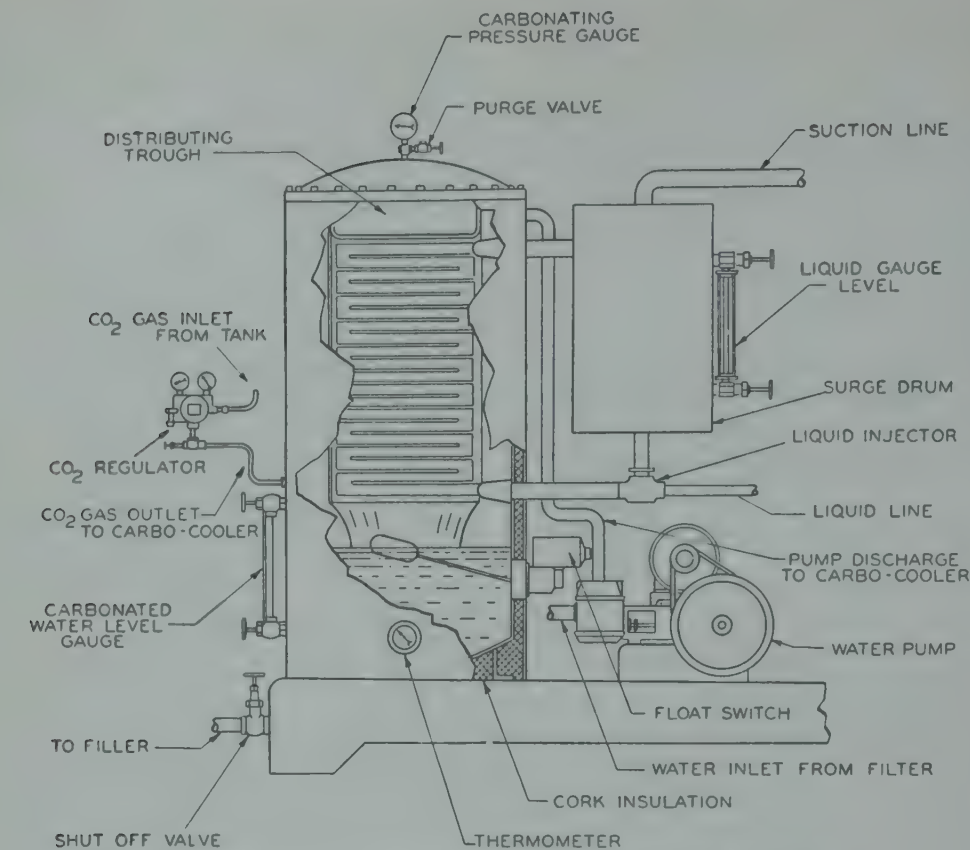

Fig. 3. Section of Carbonator-Cooler Unit for Water in Bottling Plant.

which use water at supply temperature or less, (b) those which operate with water at 45 to 55 F, and (c) those which require water of 40 F or lower.

If filling machines use water at the temperature of the **water supply,** they must hold a pressure against the carbonated water continuously during the filling process and the crowning of the bottle. It is claimed for this system that extremely stable carbonated water is not needed, since the pressure maintained prevents loss of carbonation. This filler will nevertheless operate at lower filling pressures if the water is cooled, and a more uniform product is likely to result. The exact temperature to which the water should be cooled in this instance depends on the wishes of the particular plant.

Those operating with water at temperatures in the range of 45 to 55 F are the **intermediate** type. Due to their valve design, they can release the pressure on the filled bottles before crowning, without losing carbonation. They have proved full successful. They can be made to operat with somewhat warmer water if necessar

The third class of filler requires a ver **stable carbonated water,** achieved by coo ing the water to 40 F or lower. Only wit such water temperature can the best re sults be obtained; with warmer water, ir regularity of the finished product is likel to occur.

In every installation it is important t determine the type of filling equipmer first.

Refrigeration Load

The refrigeration load is determined b the amount of water being cooled per un of time. Since most of the cooling units ar of the so-called **instantaneous** type, ther is little cold water reserve, and they mus be able to furnish continuously the desire output of cold water, without relying o storage reserve.

To determine the water demand of th

given equipment, the maximum fluid output of the filler should be determined, which is usually found when filling quart bottles with carbonated water. Under these circumstances the commonly used commercial units will require from 2 to 16 gal per min of water, depending, of course, on their size and design. Where several units of the same size are installed they will require multiples of the basic water demand.

Knowing the temperature of the water from the supply pipe or system before cooling, the temperature to which the water is to be cooled, and the water demand in gallons per minute, the tons of refrigeration can be determined by the following approximation:

Gal per min of water × (water supply temp, °F—cold water temp °F)/24

For example, given the following—	
Temperature of the water from the mains, °F	70
Temperature of the cold water desired, °F	45
Water demanded, gal per min.	16

Substituting these values in the above equation, we find that the answer is 16.66 tons of refrigeration. As is obvious this is based on the degree-gallon unit of refrigeration, which at the rate of 24F-gallon per minute is the equivalent of one ton of refrigeration.

On the computation of the load one of the most troublesome values to determine accurately will be the highest temperature the main water can be expected to reach, which occurs usually in the hottest summer periods. Moreover, one must allow for additional warming of the water going through water filters or treatment equipment, in the bottling plant. If the refrigeration equipment is to deliver uniformly cooled water of proper temperature under maximum demand, an ample figure must be allowed.

The extent to which water will rise in temperature as it progresses in the filling equipment depends on the insulation of the equipment and pipes. Newer types of apparatus are well **insulated.** In poor installations, or those in which the insulation has become wet or damaged, the gain may reach and even exceed 10 F. Therefore, this factor can best be judged by the individual plant installation.

Size of Plant and Area of Distribution

The output of various plants depends basically on the **bottle filling capacity** of their machinery. The smallest individual units requiring a large amount of manual manipulation will turn out approximately 30 cases of 24 bottles each of splits (approximately half pint capacity) per hr. Intermediate sizes, semi-automatic, will turn out about 60 cases per hr; fully automatic machines begin at approximately 75 cases per hr and go through several increases in size on to the largest units which approach 400 cases per hr.

The operation of these machines, which also determines the demand on refrigeration machinery, is usually not to exceed 8 hr per day. It may be found often, however, that in cold weather when the demand for bottled carbonated beverages is less, operation may be only on intermittent days and, conversely, in extremely hot weather it may be necessary to operate several 8-hr shifts a day to meet the demand.

On this above case output, an arbitrary classification of plants may be those with the smallest type of equipment which will put out approximately 25,000 cases per year; intermediate may be in the range of 100,000 cases per year; while the larger equipment and large plants may be 200,000 or more cases per year, which latter require installation of multiple bottle filling equipment lines.

The usual area of **distribution** of the finished beverages is within the metropolitan area of the city in which the plant is located. Some plants, however, have built up such a reputation for their goods that they may ship to warehouses up to several hundred miles distant, from which local distribution is made. A few nationally known products are shipped quite long distances from the producing plant for specialized markets. The transportation of the beverages does not require refrigeration, although it is advisable to protect the bottled goods against excessive temperature or direct sunlight. The beverage, at

the point of consumption, is customarily cooled to temperatures in the neighborhood of 40 F for a maximum refreshing effect.

Syrup Cooling

In some plants, **cooling** of the **prepared syrups** has been found to promote more uniform beverages. This is particularly important in the type of filling units in which the washed bottle is first given an amount of syrup called a "throw," to which is added about five times the volume of carbonated water. When this syrup is extremely warm, it causes excessive bubbling and gas loss from the beverage when the bottle is opened to the atmosphere before crowning. In these instances cooling units, most often of the Baudelot or tube-in-shell type, are used to bring the syrup to 50 F or lower. The original syrup may be at the temperature of the storage area or may even be higher if the syrup is prepared by heating.

The **cooling load** from syrups can be estimated similarly to that of water, as given by the above approximation. However, it must be remembered that the syrups commonly used are of fairly high density, in the range of 27 to 34° Baume (50 to 65 percent sugar by weight), and at about 60 F may have very high viscosities (30 to 50 centipoises or more), which will make heat exchange from these syrups much slower than that to be expected when using water in a given piece of equipment. Likewise, the cooling surfaces must be readily cleaned after use so that there can be no opportunity for residues of syrups to remain and allow the development of spoilage organisms which will contaminate subsequent syrups.

Since in most filling equipment the syrup and water are not completely mixed, it is necessary either to invert the bottles by hand to mix the heavier syrup with the water, or to use mechanical mixing apparatus which will invert the bottle a number of times, giving complete blending into the finished product. Because virtually none of the output of the plant is consumed directly from the filling machine, the resulting temperature of the finished beverage, because of heat gain from the bottles and syrup, is not important so long as the carbonated water remains stable during filling. No refrigeration is needed on the goods after bottling and they are allowed to warm up to room temperature **in storage,** not being again cooled until just before consumption.

Low Pressure Liquid Carbon Dioxide Storage

Carbon dioxide for carbonating water and beverages has been furnished for many years compressed and liquefied in steel cylinders designed for pressures up to 1500 psi. Larger users have utilized solid carbon dioxide which can be shipped without the extra weight of cylinders, employing converters consisting of steel pressure vessels with large access hatches designed for gas equilibrium pressures in the neighborhood of 1000 psi at room temperatures. However, in metropolitan areas it is possible to get liquefied carbon dioxide delivered to the plant in trucks from which the liquid can be piped to large storage-converter tanks of special design and equipped with mechanical refrigeration. The typical unit of this type (Figure 5) is maintained at internal temperatures not in excess of 0 F so that the equilibrium pressure of

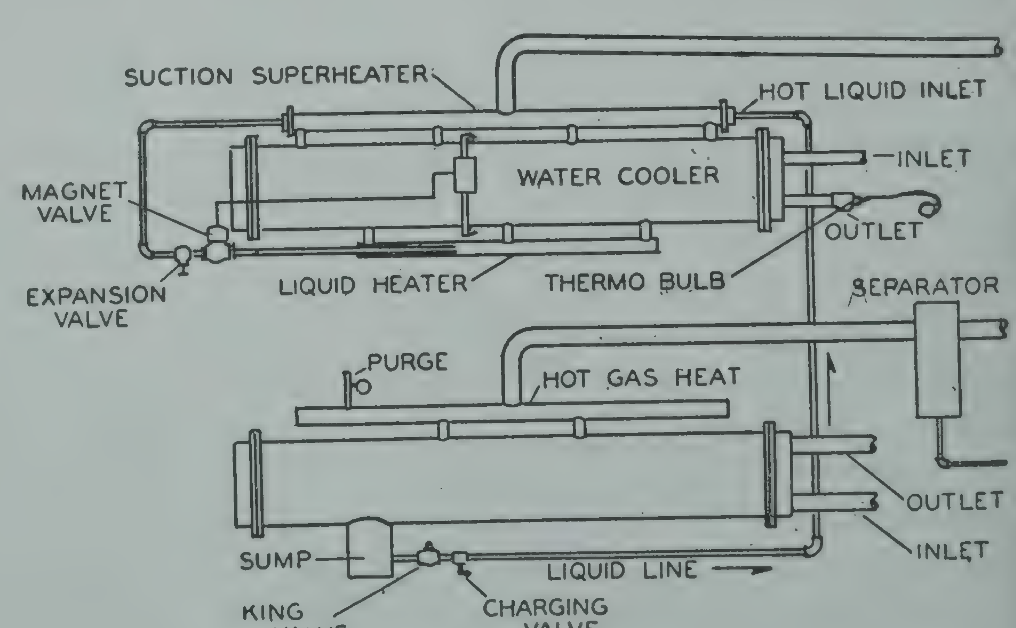

Fig. 4. Freon Evaporator Designed for Water Cooling.

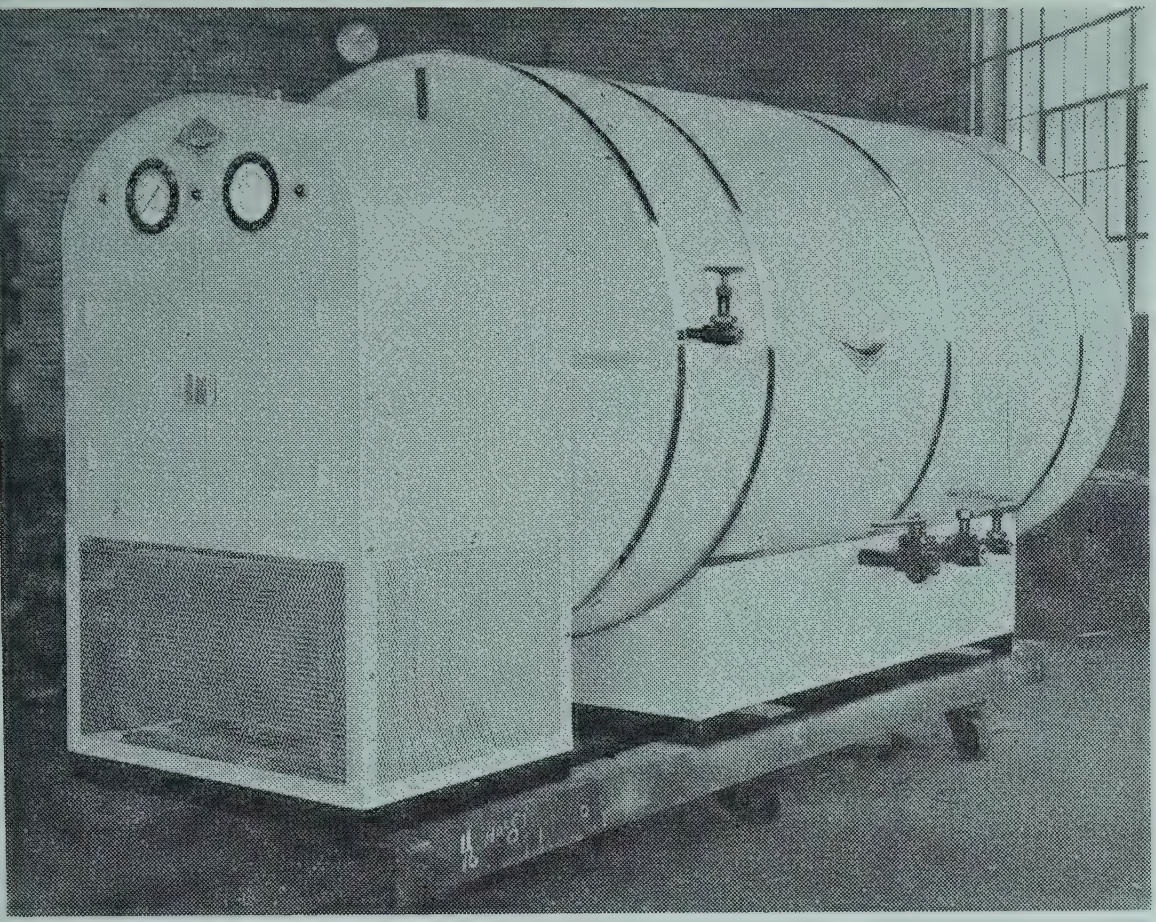

Fig. 5. Liquid Carbon Dioxide Storage-gasifier Tank Operating at 300 psi and 32 F, Controlled by Mechanical Refrigeration. Capacity six tons of liquid CO_2 stored in the heavily insulated pressure tank.

carbon dioxide does not exceed 300 psi. By this system very large storage capacity can be obtained with attendant savings and the storage tanks need not be built for excessively high pressures. Full control equipment is provided for the refrigeration, and relief safety valves of ample capacity prevent excess pressure build up. The employment of the refrigerating effects of the gasifying carbon dioxide as the sole means of temperature maintenance has proved to be more expensive than properly designed mechanical refrigeration.

Beverage Dispensers

For point-of-sale consumption beverage dispensers are used which embody either the use of ice or mechanical refrigeration. The simplest device employs cracked ice in a water-tight box, properly insulated, built of such depth to accommodate the bottles standing upright. Naturally, such a cooler will be of the **wet type,** in which the cooling of the bottle is accomplished by water contact.

Mechanical refrigeration units comprise substantially the same set-up of an insulated compartment for the bottles, cooled, however, by the direct expansion coil of a refrigerating mechanism very similar to that found in commercial and household units of fractional horsepower size. The actual means of cooling the water may vary with the particular design, employing water contact (wet system), the **dry system** in which bottles contact chill plates, or a combination dry type using chill plates and forced air circulation. The wet, or water contact, type has an advantage in rather short chilling time, due to high heat transfer from the bottle, but may not be found entirely satisfactory, due to the wet condition of the bottle on removal. In this latter type, the expansion coils may be either placed in the side or the bottom of the compartment, but are normally protected from injury by impact of the bottles through the use of a protective screen.

In the dry coolers, the design is usually such that the bottles make direct contact with metallic surfaces through which heat transfer occurs. The use of a circulating fan with this type will tend to speed up the rate of heat transfer and more quickly cool the bottle.

The very rapid growth, in recent years, of the use of automatic bottle dispensing devices has markedly expanded the use of mechanical refrigeration for bottle cooling. These automatic devices, coin operated **(Figure 6)**, are for the greater part designed for the use of the air blast-chill plate type of cooling. The refrigerating devices are of the conventional design adapted principally to wall and plate cooling. Some of these devices have, in addition to their automatic dispensing load of bottles, an auxiliary precooling chamber in which the primary cooling can be done somewhat more rapidly without the necessary arrangement of the

bottle delivery mechanism. Such units must of course be serviced at regular intervals by route salesmen to keep the units filled with bottles and to check on the temperatures being maintained.

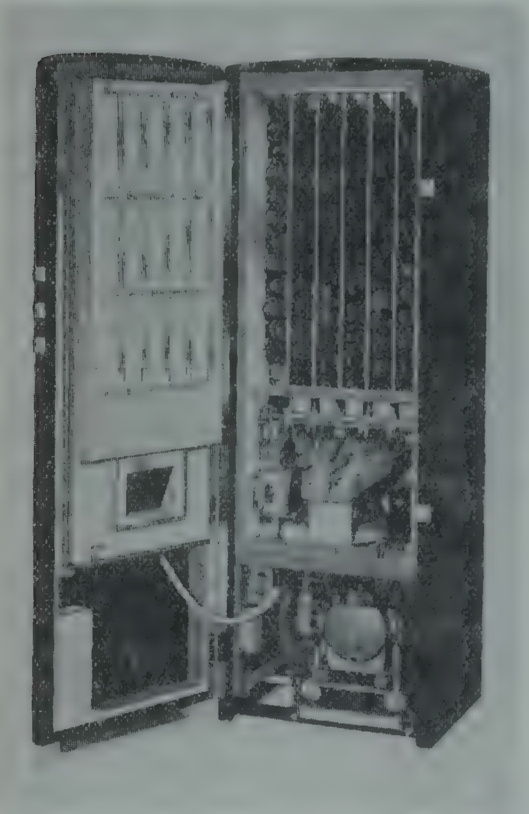

Fig. 6. A Coin Operated Vending Machine for Bottled Soft Drinks. The compressor is located in the base. Cooling in the insulated compartment is by fan driven air blast over the cooling coils upwardly through the bottles held in feed racks.

A special application of bottle cooling, although entirely foreign to carbonated beverage bottling, may be interesting because of the unusual processing steps. In the clarification of champagne type wines the aging process is carried out with the bottles inverted neck down, so that all sediment collects against the cork stopper. Finally the bottles, still in inverted position, are placed in a cold bath to a depth of several inches up the neck, freezing a plug of ice just above the cork, including the sediment. When the bottle is righted and the cork drawn, this cylinder of ice comes out leaving only the clarified product in the bottle. This process is known as disgorging or *debourbage*.

The use of the rather laborious bottle fermentation of champagne type wines has been partly supplanted in the United States by the so-called bulk or Charmat fermentation system. This apparatus is very interesting because of its use of large size, carefully controlled equipment in which there can be provided both refrigerating coils to lower temperature and water circulating coils if temperature raise is desired. The lowered temperatures are useful for two purposes—namely, to control the deposition of sediment from the bulk wine, the process commonly known as detartration, and to control the rate and character of fermentation to develop the best characteristics of the wine. Each of these plants is of highly specialized nature and the refrigeration installation will be substantially a custom design for each specific plant.

Refrigeration may be also employed with other types of still wines to promote the separation of the excess cream of tartar and to clarify the wines. It is claimed by some that at low temperatures oxygen is taken up more rapidly by the wines which results in rapid aging or maturing through the action of the oxygen. Temperatures are used at or near the freezing points of the wine, customarily about 25F and the refrigerants most likely used are Freon or ammonia. Some plants use auxiliary cooling by means of brine circulated through the coils in the tank. All equipment should naturally be made resistant to the action of the wines and should not contribute metallic contaminants to the wines to destroy any of the desirable characteristics.

If you searched this chapter for something which was not found in it, please let the editors know.

SECTION IV

REFRIGERATED FOOD DISTRIBUTION

G. A. Hayner, Associate Editor. Born 5/30/00 in Dayton, Ohio. Educated at Cornell University, ME, 1922. Formerly, Sales Engineer, Frigidaire Corp., 1926–28; Refrign. Engr., Lindsay Automatic Refrign. Co., Milwaukee, Wis., 1928–31; Refrign. Prod. Appln. Engr., Frigidaire Division, 1931–47; Manager, Prod. Appln. Section, Commercial Sales Dept., Frigidaire Div., 1947–49.

Co-author, "Study of Frozen Food Wrapping Material" and "Effect of Aging before Freezing on Beef Palatability," published in *Refrig. Eng.*

Professional Engineer, registered in State of Ohio.

At present, Commercial Product Application, Frigidaire Division, General Motors Corp., Dayton, Ohio.

Chapter	Page

35. REFRIGERATED TRUCKS

A GREAT volume of perishable products is now carried by highway trucks. These are of two types, chill temperature for fresh foods and low temperature for frozen foods. The first such trucks were used for carrying ice cream. They were cooled by ice and salt and carried inside and top bunkers. This is not very satisfactory on account of (1) the variation in cooling, as the charge of ice is decreased by meltage, (2) the weight to be carried, and (3) the deterioration of the truck bodies from the brine.

A system of cooling was developed in which **metal containers** filled with an eutectic brine and frozen in a stationary plant were hung in the interior of the truck. This system is still in use.

As a motor truck is a mechanism which requires servicing, it would seem that a **mechanical refrigerating** system could be used on a truck without entailing an additional service force, and numerous forms of mechanical systems have been successful. Two sources of power for such a system are available, either a separate internal combustion engine, or the engine which drives the truck.[1] The separate engine may operate the compressor directly or may drive a generator which supplies power to a compressor motor. This system maintains full refrigeration capacity during the time it is required, but has not been extensively applied as the cost, weight of the equipment and space requirements are high.

ALBERT F. SAWYER, Author Chapter 35. Born 7/8/95 in Haverhill, Mass. Educated at Mass. Inst. of Technology, BS, 1918; Harvard University, BS, 1921. Formerly Chief Instructor, 2nd Lt. USA, QMC 1918; Inspector Bethlehem Shipbuilding Company, 1919; Chief Draftsman, Northway Motor Company, 1920; Chief Engineer, American Motors Export Company, 1921; Chief Engineer, Icemaster Company, 1922–37; Development Engineer, Dole Refrigerating Company, 1938–49.

Contributor to *Refrig. Eng.*, AC & RN, and Refrign. Ind. Author Chap. 32, 1946 Applns. Vol. ASRE Data Books.

Member, Amer. Soc. of Refrig. Engrs. Chairman, Boston Section, ASRE.

At present, Engineer, S. E. States Dole Refrigerating Company, Chicago, Ill.

Power for the equipment can be obtained from the truck engine, either by a crank shaft extension at the front end, or by a **power take-off** from the transmission. The first method is not altogether satisfactory but all truck transmissions are so equipped that a power take-off can be easily applied. Several different methods of transferring power to the compressor from the take-off have been used.

1. An alternating current generator delivering power to an a.c. motor. The generator may be mounted in the chassis frame, and only wires need be carried from the chassis to the body.
2. A direct-current generator delivering power to a d.c. motor. This arrangement has the advantage of providing some speed correction, but it may require a dual (a.c. and d.c.) motor for the compressor.
3. Direct mechanical drive has been used, belting up through the floor to the compressor. In some cases a two-speed drive is utilized in order to obtain more satisfactory compressor speeds under different truck speed conditions. With this arrangement there is the hazard that the drive may be operated with the speed control set in the wrong position for the conditions under which the truck is operating.
4. A very few installations of a hy-

Fig. 1. Complete Gasoline Operated Refrigerating Unit of the Plug Type.

draulic type of drive have been made, consisting of a clutch of the hydrostatic gear type which transmits direct drive up to a certain speed above which the slip increases to limit the compressor speed to a safe value. The slip represents a direct power loss.

5. Attempts have been made to drive the compressor through an eddy-current slipping clutch designed to produce a constant compressor speed. The weight, cost and losses are high.
6. The system of direct mechanical drive through a magnetic clutch seems to offer attractive possibilities, and has been extensively used.

Fig. 2. Interior of Trailer Body for Transportation of Carcass Meat.

Brine and Dry Ice Systems

The compressor system may be used alone or in combination with a brine cartridge installation in what is known as an **eutectic hold-over system.** With such a system the cooling unit is a flat tank containing an eutectic brine solution and evaporator coils. The refrigeration equipment may be applied in four different arrangements as follows:[1]

1. Automatic; direct expansion evaporator with condensing unit having electric motor for plug-in power and power take-off drive, for service requiring unlimited operating time.
2. Automatic, with partial hold-over including condensing unit, motor for plug-in power and power take-off drive. This system is especially well suited to mixed interurban and city service.
3. Hold-over with condensing unit and motor for plug-in power. For fre-

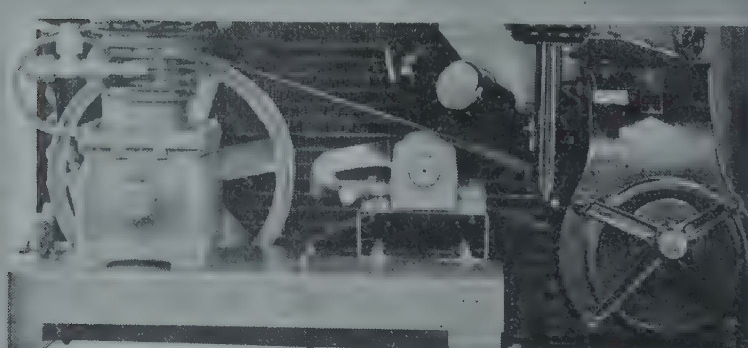

Fig. 3. Compact Gasoline-Operated Condensing Unit. It is Usually Located on Underside of Body. Note Large Condenser Across Full Width of Unit.

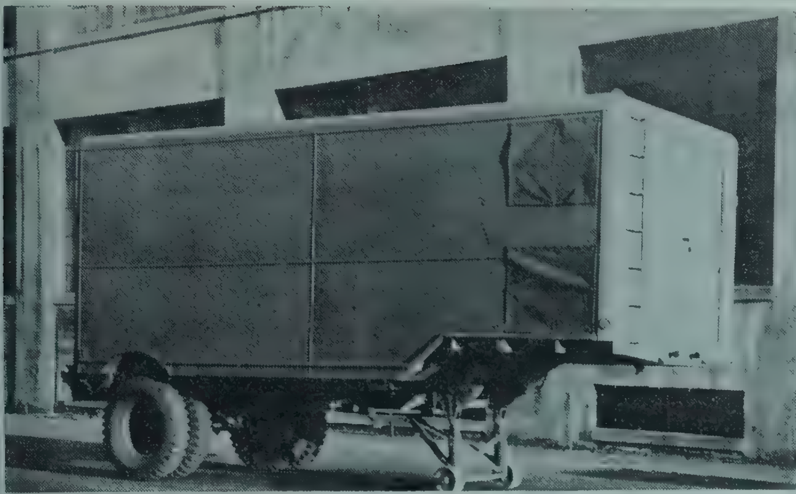

Fig. 4. Army Trailer Body with Full Automatic Refrigeration for Temperatures of 10 to 40 F.

quent stops as in city service with low daily mileage.

4. Hold-over for plant refrigeration; this system is preferred by operators using a large number of trucks operating from a central plant at which a large refrigeration system is available.

The operating conditions covered by the four arrangements vary from total independence of a stationary plant in 1, to total dependence on a stationary plant as in 4. From this range a selection can be made to suit any requirement.

Solid carbon dioxide affords a clean, light refrigerant, the use of which involves no mechanical complications. It is in extensive use for cooling truck bodies, the arrangement used on practically all installations being the dry plate system.

One or more bunkers are placed in the ceiling of the refrigerated compartment to hold the amount of solid carbon dioxide required. The tops and sides of these bunkers are insulated, but the bottom is of metal of sufficient area to provide the proper heat exchange between the air in the compartment and the refrigerant in the bunker. The cakes of solid carbon dioxide were formerly put into the bunker through a roof hatch, but the disadvantage attendant on the use of a roof hatch has been overcome by the arrangement for inside loading. (See Chapter 43.)

Ice and salt or **eutectic brine** ice are used for truck cooling in a system in which cold brine from a bunker is pumped through a coil over which air is blown by a fan into the compartment of the truck which is to be refrigerated (cold jet system). The fan and brine circulating pump are operated by an internal combustion engine. The temperature of the truck body is controlled by the truck operator, who times the operation of the equipment to produce the required temperature. An indicating thermometer is provided to show the truck temperature. There are said to be about five hundred trucks operating with this equipment.

Fig. 5. Army Trailer Interior Showing Evaporators Overhead.

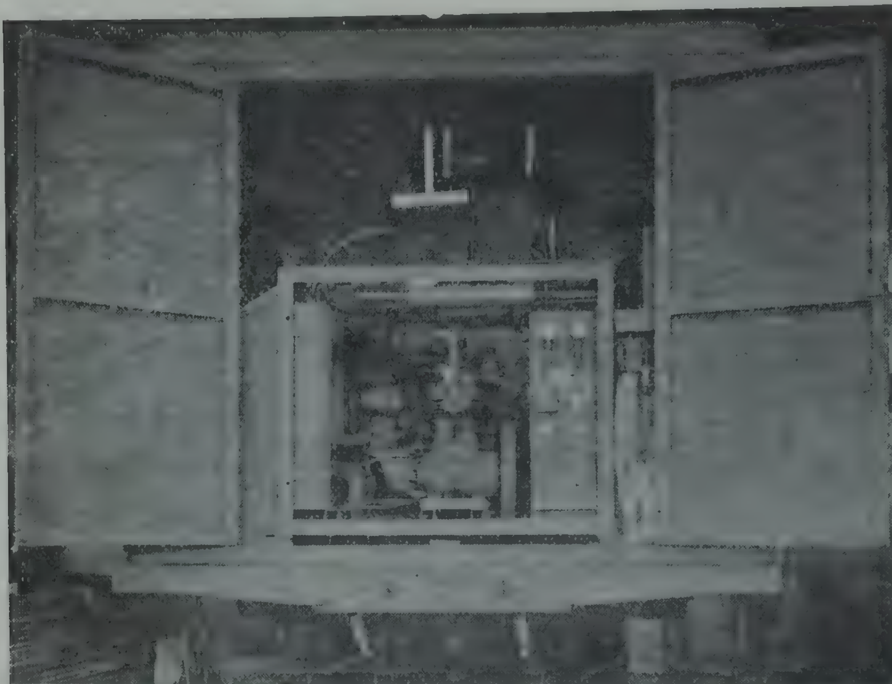

Fig. 6. View of Gasoline Operated Condensing Unit in Army Trailer.

Eutectic brine ice in suitable form such as frozen water ribbons is used for truck cooling by employing an overhead bunker with metal bottom.

Gasoline-operated refrigerating units in combination with forced air evaporators within the body are being used widely in packing and allied industries and provide good results, especially in the body temperature range of 40 to 45 F. They are relatively light in weight and require only a small proportion of the loading space in the body. Some types are in two parts with the connecting refrigerant tubing and wiring installed in the field, while others are in one complete assembly, the evaporator portion passing through a rectangular opening at the front end of the body near the ceiling **(Fig. 1)**.

A fan behind the fin coil forces air over the top of the load toward the rear of the body where it circulates back through and around the load. Since coils tend to pick up moisture in the air, some provision must be made for defrosting of coils. A convenient method is by means of a hand or solenoid valve which allows hot gas from the compressor to pass into the coils, thus melting off frost.

One manufacturer provides an 8-hp gasoline-driven unit weighing about 750 lb, equipped with generator, starter and storage battery for a completely automatic operation by thermostat. With proper body insulation, this would operate a trailer body up to 28 ft in length. Tests indicate a warm body with no product load may be cooled from 85 to 45 F in less than $1\frac{1}{2}$ hr.

Bodies for low temperature (0 F range) are usually built with 6-in. cork equivalent insulation. Floors are recommended of cork or rigid type insulation with walls and roof of glass wool, dry zero or similar light material in batt form. Loose material is not recommended. Recent practice is to slightly compress insulation laterally on walls to prevent settling.

High temperature bodies (35 F range) commonly use 3 to 4-in. insulation for economical operation. All refrigerated bodies should, of course, be vapor sealed on outer walls to prevent moisture infiltration.

Products to be carried in refrigeration bodies should always be cooled to the temperature at which they are to be transported. For instance, fresh meats and vegetables to be held at 35° in body must be pre-chilled sufficiently long in the storage space to insure the products are thoroughly

cooled. A warm load may represent thousands of heat units to be removed before body temperature can be brought down to where it should be. Numberless complaints have been made because operators fail to comprehend this principle. In the same manner 0° bodies must have products fully frozen to 0° or preferably −10°, before loading in transport vehicle.

On long hauls, floor racks should be provided as well as dunnage strips on walls so air can circulate freely and maintain even temperature. Allowance may also be made for fresh air and air circulation through the load depending on product characteristics.

The importance of the right type of insulation, properly installed, and sealed against moisture infiltration, cannot be emphasized too strongly. Faulty examples of 3 inch insulation on low temperature bodies and $1\frac{1}{2}$ inch on high temperature are all too common. They may get by for a while under 70° weather but perform sadly at 95° ambient.

Computing Cooling Surface

As with any refrigerated compartment, it is necessary to balance heat leakage through walls with sufficient interior cooling surface. Cooling surface may be blower, fin surface or plates (Figs. 1 and 2). The cooling surface in turn is balanced with the proper condensing unit. As an example with holdover plates, a body may be considered as used for ice cream delivery.[2]

- Exterior dimensions, $102 \times 72 \times 43$ in. high
- Insulation, 6 in. cork equivalent
- Maximum ambient temperature, 100 F
- Average body temperature desired, 0 F
- Temperature of product entering body, −10 to −20 F
- Time of truck on road, 14 hr
- Service, normal, 50 to 60 stops.

Heat gain hourly = 206 (outside surface in sq ft) × 100 (temperature difference) × .3 (K for 1 in. insulation) ÷ 6 (inches thickness) = 1030 Btu per hr. Outside area of body is taken rather than mean area between inside and outside in order to balance losses due to construction. Where sun effect is a serious

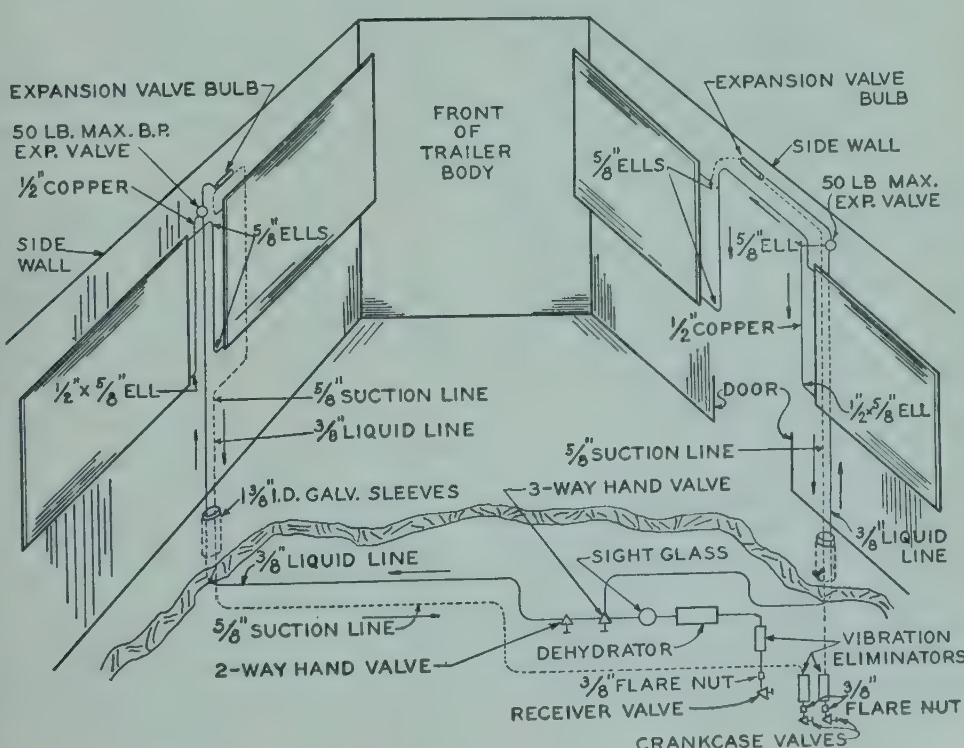

Fig. 7. Layout for High Temperature Body with Plates Mounted on Walls.

factor and must be taken into account, heat load may be calculated on the basis of one-half the body surface at 120 F ambient. Estimating 50 percent of the hourly heat gain for service, the hourly daytime load will be 1545 Btu per hr. Based on 14 hr of daily operating time, the holdover capacity required for plates is 14×1545, or 21,630 Btu.

Holdover plates for this application are usually supplied with eutectic solution, freezing or melting at −6 to −8 F. It might be assumed that for body temperature of 0 F, plate surface be figured on 6 to 8 F temperature difference. However, practice has indicated that 15° temperature difference be used for calculating surface, this figure offsetting two operating factors: (1) The ice cream being loaded at −10 to −20°; (2) subcooling of the eutectic solutions, perhaps as low as −25°.

Now, using 2.0 U factor (transmittance factor, air to plates) ×15° temperature difference, each square foot of surface will absorb 30 Btu per hr. Dividing hourly daytime load, 1545 Btu, by 30, results in 51.5 sq ft of plate surface required. Checking with standard plate sizes, probably 3 plates 24×54×2$\frac{5}{8}$ in. would be used, totaling 54 sq ft. These may be placed vertically or horizontally. It is desirable that overhead plates be pitched slightly to improve circulation.

The surface is now known, but manufacturers' tables should be referred to for total holdover capacity. The 3 plates must total at least 21,630 Btu. capacity for 14-hr operation. Tables give a capacity of 10,150 Btu for one plate of this size; consequently three plates would hold body for about 20 hr.

To select a condensing unit for this layout the daytime hourly load is multiplied by the number of hours of truck operation which is 1545×14, or 21,630 Btu. This is added to 10-hr night load of 10,300 for a total of 31,930 Btu each 24 hr. This load must be handled by the condensing unit in a 10-hr period, so the rating should be 3193 Btu or more at about −19 F suction.

When a truck operates on a daily route and the road period lengthens to 15 or 16 hours, as may be the case with ice cream trucks in hot weather, the charging period correspondingly shortens, perhaps to 8 or 9 hours. This condition would require a condensing unit with considerably more capacity than that for a truck 10 hours on the road and 14 hours allowable for charging.

Fig. 3 shows a gasoline-operated condensing unit specially designed for truck refrigeration. It is usually mounted unde[r] the body on one side but may be in a well ventilated compartment constructed in th[e] body. Compactness is necessary, but ac[]cessibility to parts must not be sacrificed[.] Regular check-ups must be made in orde[r] to avoid breakdowns.

Refrigerants Used

If a central plant ammonia installatio[n] with excess capacity is available, this pro[]vides an excellent system for a fleet of re[]frigerated trucks. Liquid and suction line[s] are usually installed in the garage, and re[]frigerant connections to bodies are wit[h] flexible hoses and suitable hand valves an[d] unions. Using ammonia, the expansio[n] valve is usually mounted on the garag[e] wall, ammonia from the valve expandin[g] into in-going hose. Methyl and Freon in[]stallations usually have the expansio[n] valve on the truck side. Care must be use[d] with low pressure refrigerants in makin[g] and breaking connections to prevent ai[r] and moisture from entering the system[.] Ammonia is more fool-proof in this respec[t].

Where brine is available at −15 F o[r] below, it may be used to advantage wit[h] holdover plates. The brine is circulate[d] through the steel tubing in the plates, thu[s] freezing the eutectic holdover solutio[n] within them.

Government Installations

The Army and Navy are using man[y] truck and trailer bodies for the transporta[]tion of frozen foods. **Figs. 4, 5** and **6** sho[w] a trailer body about 8 ft wide by 7 ft hig[h] by 20 ft long, inside dimensions. Floor [is] 6-in. corkboard and walls and roof 5- an[d] 6-in. Fiberglas, respectively. Inside an[d] outside walls are steel.

A Freon-type air-cooled condensing uni[t] is located in the compartment at front o[f] body. It is operated by fully automati[c] 12-hp gasoline engine with V-belt driv[e]. Holdover type plates are located overhea[d] in the body, and a control mechanism hol[ds] body temperatures closely in the range be[]tween 10 and 40 F. A test made on a sam[]ple body at ambient of 120 F with n[o] product load showed a pull down to belo[w] 10° inside in less than 8 hr. During th[e]

next 24 hr the unit cycled three times. On shutting off unit, the body warmed to 30 F in the following 40 hr.

Installation of Cold Plates in a Truck or Trailer Body

Fig. 7 shows a layout for high temperature body with plates mounted on walls. Plates are placed $1\frac{1}{2}$ to 2 in. from walls with top edges 6 to 8 in. down from ceiling. Hangers must be securely bolted to walls, preferably by fastenings incorporated into the studs. It is not advisable to fasten hangers by bolting through the body to outside. A drip trough is used under each plate. If necessary to protect plates from load, guard rails should be placed about 1 in. away from plates.

Plates are cross connected with $\frac{3}{8}$-in. O.D. copper tubing, using sweat or flare type connections. For ammonia type installations, $\frac{1}{2}$-in. extra heavy pipe is used. Short connections are to be avoided as vibration may cause breaks in pipe or tubing. Vibration eliminators are used at condensing unit.

Ice cream delivery bodies may have holdover plates on ceiling, on walls, as partitions, or a combination arrangement; **the important factor being sufficient plate surface to maintain temperature.** One or more curb side doors afford reach-in access to goods. This layout is also satisfactory for frozen foods delivery but many operators prefer a walk-in model with door at rear. A center aisle is provided with products on shelves on each side. Holdover plates serve as upper shelves, thus performing a double duty with very little waste space.

Proper layout and installation cannot be too strongly emphasized. Many jobs have been doomed to failure before going into service because of lack of thoroughness in the original planning.

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If you searched this chapter for something which was not found in it, please let the editors know.

36. LOCKER PLANTS

A FROZEN food locker plant is an establishment where foods are frozen and held in storage at a low temperature for a community group of patrons (families and others). The principal components of a typical plant are as follows:

1. A **chilling room** where fresh killed meat is chilled, and other food products are held under refrigeration prior to processing and preparation for freezing.

2. An **aging room** where certain meats, such as beef and mutton, are allowed to hang in carcass form for several days (usually 10 to 15) for the purpose of improving tenderness and taste. This room is refrigerated.

3. A **processing room** or rooms where meats are cut to order, fowl is cleaned and dressed, and all types of meats, fruits and vegetables are prepared, packaged and identified prior to freezing.

4. A **freezing cabinet or room** in which all foods are completely frozen prior to storage in the patron's individual locker.

5. A **locker room** containing from a few to several hundred lockers for rental to individuals for long-time food storage. This room is held at a constant and uniform low temperature. Foods stored retain their desirable qualities of freshness, vitamin content, taste, texture and appearance over a period of several weeks or months as desired.

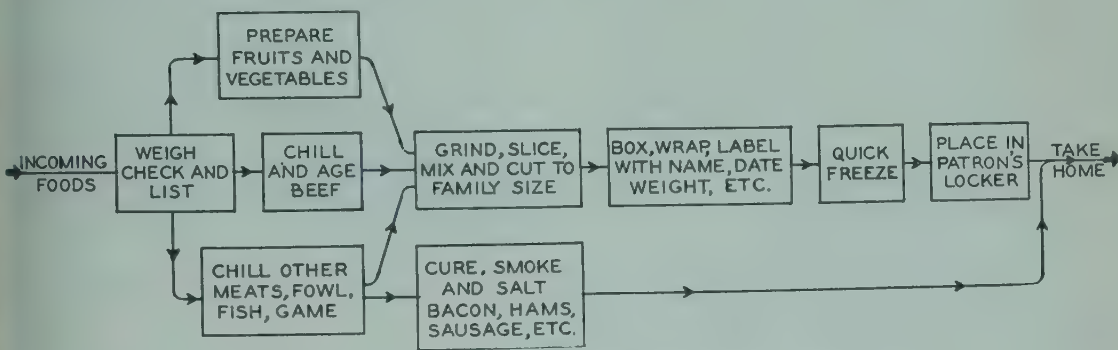

Fig. 1. Flow Diagram of a Frozen Food Locker Plant.

Fig. 1 shows the steps through which various foods pass in a modern locker plant. Special attention should be given to the relative locations of various component parts of the plant so that the flow of food products may be accomplished with a minimum of handling time and expense. Refrigeration of such a plant is accomplished by modern automatic refrigeration equipment.

Many factors influence the construction of a plant, and it is important that a thorough study be made before construction begins. Materials available, services to be rendered by the plant, size of the plant, type of building (either existing or to be built), location of building, affiliated business if any, and other factors in addition to

J. A. Smith, Author Chapter 36. Born 5/3/95 in Piqua, Ohio. Educated at Bradley Polytechnic Institute, Peoria, Illinois. Formerly Principal, High School, Swayzee, Indiana, 1915–16; Assistant Supt., Piqua Handle and Mfg. Company, 1916–18; U. S. Army, 1918; Delco-Light Company and Frigidaire Corp., Service, Sales and Engineering Depts., 1919–29; Distributor, Delco-Light Products, Chicago, Ill., 1929–33; Frigidaire Division, General Motors Corp., Dayton, Ohio, Service and Sales Depts., including Zone Manager, Branch Manager, Manager of Farm and Locker Plant Sales and Manager Product Applications, Commercial Dept., 1933 to date.

Author of numerous papers for trade publications; Chapter 33, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engrs.; Past President Frozen Food Locker Institute; Engineers Club, Dayton, Ohio.

At present, Manager, Product Applications, Commercial Sales Dept., Frigidaire Division, General Motors Corp., Dayton, Ohio.

the type of refrigeration to be used are reviewed in this chapter. An engineer cannot reasonably be held responsible for the operating characteristics of any plant, unless the principal components are specified, selected, and installed according to his specifications and plans. These include such items as insulation, cold storage doors, condensing units, evaporators, controls and building construction.

It is necessary to take into consideration **state laws** and local ordinances, some of which regulate chill room and storage temperatures, freezing conditions, temperature records, kind of refrigerant and other features. Facilities for health protection are also provided for in many state regulations, while local ordinances may govern the operation and location of slaughter houses, and the inspection and sale of meat.[1]

In the commercial frozen food industry a number of different methods of **freezing** are used. Of these, only a few are practical for locker plant applications. Since a locker plant is required to handle a wide variety of products, it is necessary to select a method which will permit the plant operator to apply it to all of the foods to be frozen. The "blast freezer" or the "contact freezer" has been specified for the great majority of plants. Either method is well adapted to the handling of miscellaneous products in packages of varying size and shape, and will freeze with sufficient speed to satisfy the most critical processor. Regardless of which method is used, it is well to keep in mind that the freezing should be accomplished with reasonable speed in order (1) to produce a high quality product, and (2) to have as much food as possible pass through the freezer in a given amount of time.[2,3]

The **storage requirements** for frozen foods in the commercial freezing plant or the frozen food locker plant are identical as to temperature and general conditions. A temperature of 0 F with a normal variation of plus or minus 2 to 3° is generally considered practical and satisfactory.[4] The humidity in such storage rooms should be kept as high as practical by designing the plant with a narrow split in temperature between the room temperature and the refrigerant temperature.

Fig. 2. Polar Chest-Freezer Rack.

Plant Classifications

Most locker plants are of the **walk-in** type, with all facilities on one floor level. A few cases are on record, however, where a part of the plant or all of it, due to space limitations, has been located either in a basement or on the second floor.

Plants of other types known as the **warm-room** have been built which allow the patron to secure frozen foods from his locker without entering a low-temperature storage room. One such type plant is known as the "Polar Chest," in which the locker and freezer sections are installed beneath the floor level. Each locker tier and each freezer rack is covered by a separate insulated section of the floor **(Fig. 2)**.

Another "warm-room" design known as the "Salem System" also provides for the patron's access to the locker without entering a low-temperature storage room **(Fig. 3)**. In this system, the locker tiers are mounted on a small platform which is attached to an endless chain. The chain

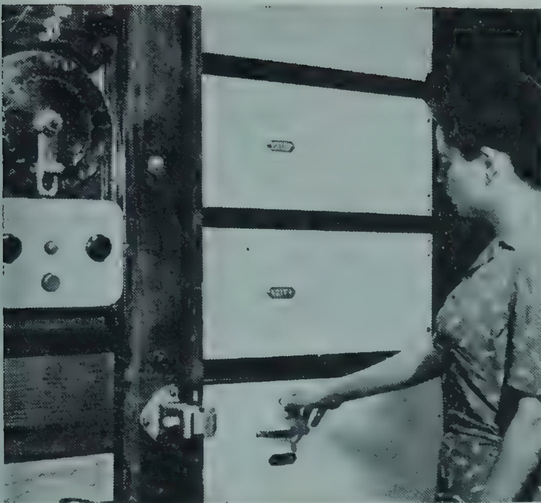

Fig. 3. "Salem" System Installation.

passes around sprockets geared to an electric motor, which causes the lockers to travel around a two-way track and come to the desired position behind the service door.

Other "warm-room" type plants use prefabricated locker and freezer assemblies which may be classed as the reach-in type. They are installed in a normal temperature room and are accessible to the patron in the manner of the baggage locker in the railway station. Some of the better known among this class are the "Iceberg" and "Kold-Cell."

The frozen food locker plant must be designed to furnish the various services which the prospective operator may want to provide. The average plant should be equipped to handle meat as 75 to 80 percent of its volume. The services to be rendered should, therefore, be planned accordingly. These services consist of chilling, aging, cutting, wrapping, freezing and storing. Operators in some areas will want to provide additional meat services such as pickling, smoking, lard rendering, slaughtering, poultry dressing, sausage making, grinding, etc. Other services for the handling of fruits and vegetables will constitute from 20 to 25 percent of the plant activity and will consist of cleaning, blanching, packaging and freezing.

Plants which may perform only parts of the services[6] outlined above are usually referred to as "limited service" plants. It has been found, however, that most patrons are willing to pay for other additional services. Such decisions will be influenced by the community, the type of patron and other nearby plants. Some patrons will produce everything which they bring into the plant for processing, while others will buy their meats in primal cuts. Some will produce their own fruits and vegetables for storage, and some will buy them. Meats from popular brand packing houses are often in great demand by patrons. Even the farm producer who raises hogs only, for example, will often want to vary his menu with a few choice cuts of beef. In certain areas the processing and storage of game is a major item, and the plant operator must therefore recognize the need for special facilities.

The percentage of townspeople or other non-farmers who may be expected to patronize a plant is usually much less than farm families. Some observers maintain that 10 percent is a reasonable figure to apply to this group for some of our smaller towns and villages in general farming areas.

The patronage of locker plants by farmers in many areas will run from 70 to 90%. The distance to a nearby plant, the kind of service available and the length of time it has been in operation are factors which affect usage.

Design and Construction

A locker plant must be designed to handle a wide variety of foods. It is therefore necessary to provide facilities to handle properly the various kinds of locally produced foods, as well as others which may be brought in by patrons.

Chilling. Meats, fish, fowl or game should be chilled immediately after killing. Thorough chilling at this time produces a better flavored product and facilitates the handling and cutting. The approximate chilling time of various items is as follows in **Table 1.**

Products of Table 1 should be held in the chilling or aging room until prepared for freezing. Beef, to be aged, should be hung in the aging room at approximately 35 F for several days as desired. Vegetables should be cleaned, packaged and

frozen as soon as harvested, the same day, if possible. For this reason, chilling is usually unnecessary unless overnight storage is required during peak season. Some fruits may be held for a short time in the chill room at 35 F to make them firmer and more suitable for handling. This depends upon their degree of maturity. Other fruits and berries should be cleaned, packaged and frozen as soon as possible.

Table 1. Approximate Chilling Times, hr

Food	Time at 35 F
Beef (halves or quarters)	36 to 72
Pork, lamb and veal	24 to 48
Poultry and other fowl	5 to 10
Fish	2 to 5

Chill room temperatures may vary from 34 to 36 F, but for purposes of calculation, it is suggested that 35 F be used. (Many plants are provided with rooms for curing meat. The design temperature of these rooms should usually be 38 to 40°.) During the process of cutting, wrapping or packaging, and labelling, there will be some rise in temperature of the products being handled. To keep this rise to a minimum, it is suggested that meat and other products in process be allowed to remain in the chill room until they are ready to be handled and that they be placed in the freezer as soon as possible.

Freezing. After packaging, the next step is that of freezing. The items to be frozen should be arranged in the freezer in such a way that freezing may be accomplished with reasonable speed to produce a better product, and so the food will pass through the freezer rapidly enough to utilize fully the productive capacity of the equipment. Freezing of family-size packages with suitable speed may be done satisfactorily in a locker plant by several different methods such as:

1. Contact freezing by placing the product in contact with low-temperature plates or coils, using refrigerant temperatures of −15 F or below.
2. Contact freezing with the assistance of a blast of air over the products to be frozen.
3. Blast freezing in air with the air temperature anywhere from 0 F downward.

Freezers are usually of such capacity that two or three loadings per day are possible, delivering product at approximately the temperature at which the food is to be stored.

The reduction of temperature of the foods being frozen to temperatures far below the ultimate storage temperature is wasteful and unnecessary.

Storage. Practical experience by plant operators and research by food technologists and others has shown that 0 F is the proper design temperature for locker room storage.[4] Some of the earlier plants were designed to operate at storage temperatures as high as +15 F. Because of the increasing use of frozen food locker plants for the storage of fruits and vegetables, and to increase the time limit for meat storage, it has been necessary for many of these earlier plants to change their storage temperatures. Some of them have been content to do a partial job of correction by

Table 2. Approximate Storage Period for Frozen Foods

(See also Sections I and II)

Product	Approximate storage period, months		
	At 0 F	At 5 F	At 10 F
Fruits, vegetables, beef, veal	10 to 12	8 to 10	3 to 4
Lamb, mutton, poultry, eggs	8 to 10	6 to 8	3 to 4
Pork, butter	6 to 8	4 to 6	2 to 3
Ground meat (unsalted), cream	4 to 6	3 to 4	1 to 2
Bacon and ham (mild cured, not smoked)	4 to 5	3 to 4	1 to 2
Fish, ground meat with salt in seasoning	3 to 4	2 to 3	1 to 2

providing temperatures of +5 or +10 F. Table 2 shows approximate storage periods possible.[8] This table is submitted here as further evidence that 0 F should be generally recognized as the proper design temperature for locker storage rooms.

Suitable design recommendations for the average frozen food locker plant are given in the condensed Table 3.

Capacity requirements. The average locker holds approximately 6 cu ft. Under average conditions, each cubic foot will hold a maximum of about 40 lb, therefore, 240 lb per locker is a safe basic figure as to total capacity at any time. Assuming a yearly turnover of three, each locker will accommodate about 720 lb per year. This is approximately 2 lb per day per locker. This figure has been used by many engineers as a base for product load calculations.

The NEMA standard for farm and home freezers is 35 lb per cu ft, 40 lb per cu ft is used here, however, since the contents of a locker plant are relatively higher in meats, such as beef and pork, which weigh somewhat more per cu ft than vegetables and

Table 3. Locker Plant Design Conditions

Type of space	Room temperature	Refrigerant temperature	Insulation thickness, in.[1,7]
Work room, process room and kitchen	Atmospheric[2,6]	None	None
Chill room	34 to 36 F. Design for 35 F[3,6]	20 to 25 F below room temperature, for gravity circulation; 10 to 15 F below room temperature for forced air circulation.	3 to 8
Aging room	34 to 36 F. Design for 35 F[3,6]	Same as chill room.	3 to 8
Curing room	38 to 40 F. Design for 40 F.[3,6]	Same as chill room.	3 to 8
Freezing room (Gravity air circulation)	−10 to −20 F[4]	−20 to −30 F	6 to 12
Freezer cabinet (In locker room)	Not important[4]	−15 to −20 F	1 or 2
Blast freezer	Depends on type of system used.[4]	−10 to −15 F	6 to 12
Locker room or bulk storage	0 F[5]	−15 to −20 F	6 to 12

[1] Properly sealed and erected corkboard or equivalent.
[2] May be air conditioned for employees' comfort if desired.
[3] Chill, age and cure rooms may be operated at 32 to 40 F with reasonably good results. Chill and age rooms are usually preferred at 34 to 36 F and cure rooms a little higher, or about 38 to 40 F. It is suggested that 35 F be used as a design temperature for chill and age rooms. The refrigeration coils in these rooms should operate on a defrosting cycle.
[4] Freezing may be done in a freezer room, or in a cabinet freezer, or in a blast freezer. If a freezer room is used, it is necessary to consider both heat leakage and product load. If a freezer cabinet is installed in a locker room, the product load only need be considered, since the coiling in the locker room will take care of the heat leakage where the freezer cabinet is located. A blast type freezer may be located in a special room or in the locker room. It may be used for freezing only, or may be used to refrigerate the locker room and handle the freezing load also.
It should be remembered that freezer temperatures may show considerable variation during loading periods. The amount of variation depends principally upon:
(a) Capacity of freezer in relation to load.
(b) Size, shape and initial temperature of packaged product.
(c) Method of loading—i.e., "batch" or "continuous."
[5] Controls should be adjusted so as to hold the air temperature of the locker room as constant as possible. Variations of plus or minus 2 to 3 F are customary.
[6] Ultra-violet lamps may be used in these areas.
[7] Common walls between two refrigerated rooms should be insulated with at least minimum thickness shown.

fruits and other items of less weight per cu ft which constitute the principle contents of the average home or farm freezer.

It is not always a safe figure, however, for all functions of the plant. The **preparation and freezing** of food is not a constant factor for each day of the year. Preparation and freezing, due to other work to be done, may take place only 4 to 6 days per week in the average plant. For this reason, it is often desirable to provide space and freezing capacity for 3 lb per day per locker, in order to avoid overloading of the freezer on busy days.

The **incoming load** in the chill room is also subject to considerable variation unless each customer is required to bring in foods to be processed on a regular predetermined daily schedule. Such a schedule may be carefully planned, but it is rarely maintained. For this reason, it is best to figure a minimum of 3 lb per day per locker for the chill room load. This, too, should be increased if the chill room will be required to handle "extra" food products not scheduled for freezing and storage. Such products as pork for curing and smoking only, meats to be sold fresh at retail, fruits and vegetables for temporary storage and other similar items should be included in this group of extra food products. Some engineers have used a figure as high as 5 lb per locker per day when sizing and planning the chill room. The general use of any such high figure, however, may be a serious mistake. Good practice dictates that the chilling and aging be handled in separate rooms. Four to six square feet of floor space should be provided for aging a side of beef.

In some areas, a considerable amount of meat **curing and smoking** will be handled.[6] The demand or requirement for this service is higher in areas such as the southern states where pork constitutes a rather high percentage of the meat used. Such facilities, for pork, constitute as much as one-third or more of the plant capacity in many plants now in operation in Georgia, Alabama, Mississippi and neighboring states.

Building construction.[7] Whether the building is a new one, or an old one, it should be planned or prepared in such a way that the needs of the plant are best taken care of. Most important is the foundation. Shifting and sagging floors will cause fissures in walls and insulation. Floor loads of 200 to 250 lb per sq ft should be provided, equivalent to some types of mill construction. Floors on grade levels should be supported at close intervals with piers. Floors over excavated areas or usable basement space should be supported by steel or reinforced concrete girders.

All floors of insulated rooms which are held at sub-freezing temperatures should be laid on **well drained ground** so as to **prevent upheavals caused by ice formation and expansion.** Walls should be rigid and braced where necessary. Outside walls must be well protected against the weather. A good roof will pay dividends. See Chap. 15, 1949 Basic Volume ASRE Data Books.

Basements and second floors are sometimes considered for the location of all or part of a locker plant because of space limitations on the main or ground floor. Some plants have been installed with the locker room in the basement and with the chill and processing departments on the main floor. Others have been installed with the entire plant in the basement or on the second floor.

Because of the service demands and low temperatures needed in a frozen food locker plant, good **insulation** is highly important. Good insulation depends on both the material itself, and the method of application. The most expensive material, if poorly installed, will fail. On the other hand, it has been observed that ordinary materials, if expertly applied, will often give satisfactory service for many years. Insulation materials are usually divided into two general classes: (1) The loose fill and batt-type and (2) the slab or block-type.

Insulation materials, interior finish and framing must be free from aromatic **odors**. The asphalt and paint must also be free from odors. Aromatic odors from walls, due to wrong materials, may find their way into improperly wrapped or packaged frozen foods in a few weeks or months. Such materials as cedar shavings for insulation, pine lumber for interior finish and common tar or street-type asphalt are the usual offenders. (See Chapter 30, page 515.

1949 Basic Volume, ASRE Data Books.)

Storage rooms and freezer rooms operating at temperatures of 0 F to −20 F require 6 to 12-in. insulation. Rooms for chilling, aging and curing which are operated at temperatures above freezing, require 3 to 8 in. Common walls between refrigerated rooms should contain the minimum thickness required for the lower temperature room. If power rates are relatively high, the engineer should provide thicker insulation to compensate for these higher rates.

Small locker rooms are usually provided with **doors** approximately 2 ft wide ×6 ft 6 in. high, while larger plants are usually provided with a 2 ft 6 in. ×6 ft 6 in. door. All locker room and freezer room doors should be of the low temperature or freezer type. Utility doors approximately 18×18 in., or 18×24 in. of the same construction as doors for the locker room, are sometimes used for loading the freezer cabinet or freezer room. They are usually high enough from the floor to permit the unloading of baskets or trays from a table or truck into the freezer. Chill room or aging room doors may be of the standard cooler type with special provisions at the top for trackage, where needed. Minimum size chill room doors are 2 ft 6 in. wide by 6 ft 6 in. high. If trackage is employed, wider and higher doors are required. Glazed windows (5 thicknesses or more) are now in common use in both chill and locker rooms.

Equipment Selection

Lockers. The average size locker provides approximately 6 cu ft of storage space. The lower 3 or 4 lockers are usually of the drawer type, while the lockers in the upper part of a tier (a tier is usually 5 or 6 high) are provided with doors. Drawer lockers usually provide over 6 cu ft of storage, while the door type may run a little under this figure.

Dimensions of the lockers to be used must be determined before plans for the construction can be completed. Dimensions of popular and available sizes may be secured from the manufacturer. Three of the most popular sizes are shown in **Table 4.** Other sizes, both larger and smaller, are available and some operators like to have a few of each to take care of special customers.

Table 4. Locker Dimensions

	Door lockers		Drawer lockers to match	
	Width, ht, depth, in.	Volume, cu ft	Width, ht, depth, in.	Volume,* cu ft
1.	18×18×30	5.62	18×22×30	6.25
2.	24×15×30	6.25	24×20×30	7.5
3.	20×17×30	5.90	20×20×30	6.25

* When calculating the approximate capacity of drawer-type lockers it is necessary to deduct about 2 in. from height for track and rollers to find the approximate inside depth.

Special consideration must be given to the ceiling height of a locker room so that the lockers when installed will not conflict with ceiling installations of cooling units or interfere with air circulation.

Locker rooms with forced air type evaporators or coils should have at least 12″ space above the lockers where the air throw is 15 to 20 ft. More clearance is needed if the air throw is greater. When plate type gravity coils are used the ceiling must be high enough to allow locker doors to be opened wide without striking coils or coil supports.

Processing equipment. The layout of a locker plant should show the location of saws, grinders, work tables, cutting blocks, lard kettles, smoking cabinets, blanching kettles and other pieces of processing equipment. These items should be so arranged that a minimum number of steps is required by the operator. The selection of processing equipment items will depend upon the size of the plant, services rendered, individual preference of the operator and space considerations. Dimensions and space requirements for these items should be obtained from the manufacturer.

The amount of **trackage** needed in the chill room, aging room and processing room will depend on the plant layout and the processing to be done. If processing is handled on a regular daily basis and not allowed to accumulate, the chill room space may be somewhat less than if it is handled in batches on certain days. A chill room may need from 3 to 6 ft or more of meat rail or track, for each 100

lockers, if an aging room is adjacent. The aging room will need from 12 ft to 20 ft of meat rail or track for each 100 lockers. If a considerable proportion of beef is processed in relation to other meats, and if it is held two weeks or thereabouts, more trackage is needed. If less beef and more pork is to be handled, less trackage is needed.

For a small plant with a capacity of 100 or 200 lockers having no separation between the aging and chilling space, 20 or 25 ft of hanging rail for carcass meats, and 10 or 12 ft of lower hanging rail for smaller cuts should be provided. The combined **floor area** for the average chill and aging room should be not less than one-third of the locker room floor area. If the meat to be handled is largely beef, and if it is freshly killed when received, the total chill and aging space should be increased to one-half that of the locker room.

Experience has shown that controlled **ultra-violet radiation** in the region of 2537 Ängstrom units has a definite value for control of mold and bacteria growth when used in the chill, aging and processing rooms of a frozen food locker plant. (See Chap. 20.)

In determining the proper size and number of **condensing units** to be used, one of three general methods of selection is usually followed.

Method No. 1 provides one condensing unit of sufficient size to handle the entire plant. There are many plants now in operation equipped with one condensing unit. For the average job, this is not a good method of operation, principally because the unit must be selected to handle the entire load at the lowest and least efficient refrigerant temperature. The control problem also becomes more complicated as more control devices are needed. Methods No. 2 and No. 3, however, have so many advantages that Method No. 1 should be considered only under special conditions.

Method No. 2, which is popular with many engineers, calls for a separate condensing unit for each room, that is, one for the locker room, one for the freezer room or cabinet, one for the chill room, and one for the cure room, if a cure room is used.

Fig. 4. Chill Room with Blower.

Each condensing unit operates at the mos efficient operating refrigerant temperature There is no necessity for complicated controls.

Method No. 3 is to group the temperature functions so that all low temperatur functions are handled by one condensin unit, and all high temperature functions b another. This grouping usually include the locker room, the freezer cabinet o room, and in some cases, a zero bul storage room on one condensing unit. Th higher temperature rooms such as the chil room, age room, if any, and the cure room if any, are included in a high temperatur group on another unit.

This method has the advantage of simplified control, and it is also desirable because each condensing unit can operate a approximately its most efficient refrigeran temperature. From the standpoint of firs cost, Method No. 3 usually has some advantages over Method No. 2, and will, i many cases, compare favorably with th cost of Method No. 1. Since any of th above methods are practical and more o less acceptable, the engineer should use th

Fig. 5. Locker Room with Overhead Plate Cooling Units and Cabinet-Type Contact Freezer.

one which fits the project best, based on a study of conditions surrounding the individual job.

Cooling units. The cooling units or evaporators for a frozen food locker plant must provide the proper temperatures for three general types of refrigeration services.

1. The first is that of the **chill, aging and curing** rooms. Temperatures here are nonfreezing, and average about 35 F. Some variations may be required to meet special conditions such as in a meat curing room where the best results are obtained with a temperature of 38 to 40 F. These rooms may be handled with either forced air or gravity circulation type evaporators. They should be installed in such numbers and locations that each room has good air distribution. The temperature difference from air to evaporator should average 10 to 15 F between the refrigerant and the design temperature of the room for forced air units. If gravity type are used, they should be selected at an average of 20 to 25 F difference. With either type, modern refrigeration practice requires automatic defrosting. Forced air units are now the most popular with engineers and plant operators for the above purpose **(Fig. 4).** Many plants, however, especially smaller ones, are operated successfully with the gravity type.

2. The second type of refrigeration to consider is for **freezing.**

The **sharp freeze** method consists of a low temperature room equipped with non-defrosting overhead cooling units (plates or pipe coils), where heat transfer from the food to be frozen is dependent upon gravity air circulation. In such freezers, the design room temperature is usually -15 to -20 F with refrigerant temperature 5 or 10° lower. This type of freezer is in use in some of the older plants, but is not usually selected for the modern plant because of the larger space required, the increased investment and because freezing is often slower than with other methods.

The **contact freezer** is generally of the cabinet or room type. Low temperature plates are ideal for this type freezer. The packaged food is placed directly on them for freezing. The freezer should be as small and compact as possible, yet ample to handle the peak volume of products to be frozen. The freezer should not be used for storage purposes. Refrigerant temperatures of -10 to -20 F in the plates will provide satisfactory freezing results. If a walk-in freezer room is specified, it is good practice to install a bank of overhead plates to take care of the heat leak and service load. This is not necessary with a cabinet-type freezer which is usually installed in the locker room **(Fig. 5).**

The air temperature in the freezer cabinet or room using contact freezing is of

secondary importance. It will vary in relation to the loading. When the freezing cycle of a heavy load is completed, the air temperature will usually drop to within a few degrees of the plate temperature. If loadings are continuous, the air temperature of the freezer will show little variation. The simplicity of a plate-type freezer makes it popular.

Blast freezers were employed in a few locker plants at the beginning of the industry, but due to the defrosting problems, were not popular. During the last few years, however, many improvements have been made in these freezers, especially in respect to defrosting. With these improvements, there has been an increase in popularity and, likewise, in the number of installations. Some types of blast freezers are used for freezing only. Other types are available for both freezing and locker room refrigeration **(Fig. 6)**. The freezing is accomplished by a rapid circulation of air over the low temperature coils and the food is usually placed in wire baskets or upon wire racks. The refrigerant temperature in a blast freezer is usually selected at −5 to −10 F. If properly operated within capacity limits, a good product results.

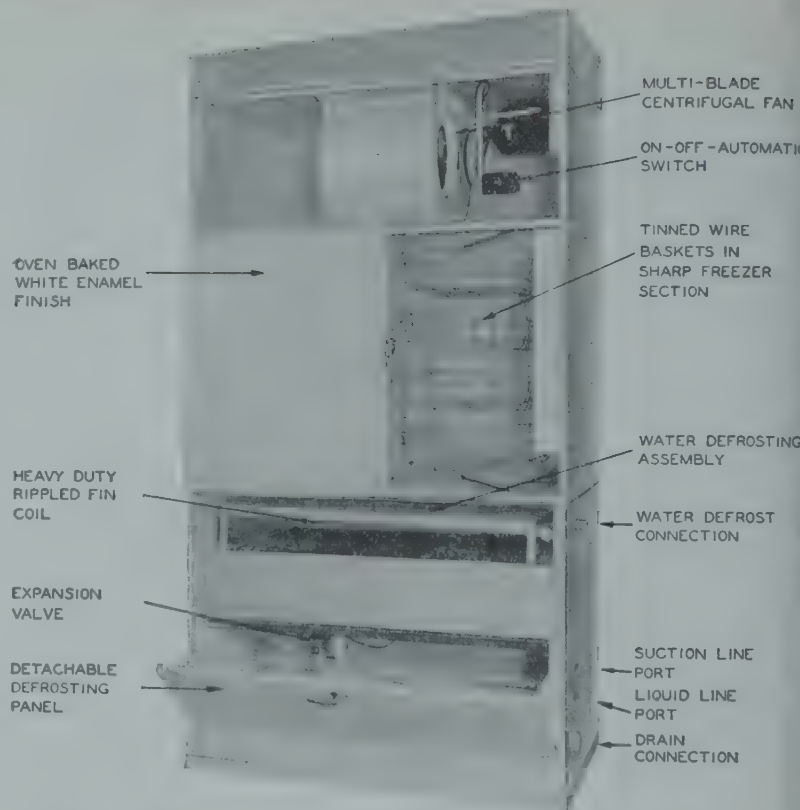

Fig. 6. Combination Blast Freezer and Locker Room Cooling Unit.

The freezing of food in a locker plant freezer should be fast enough to allow two or three turnovers or freezings per 24 hr.

3. Refrigeration of the **locker storage room** may be accomplished with gravity or forced air cooling units. Regardless of the type used, the design temperature of the storage space should be 0 F or below, with an allowable variation of ±2 to 3 F. In order to produce this result, it is necessary that the capacity of the refrigeration equipment be sufficient to handle the heat leak load during periods of peak ambients. The locker room should not be used to freeze products, but used for storage only.

If gravity-type units are used for the locker room, they should be distributed over aisles so that complete coverage is effected for the whole room. Banks of several plates each are usually used, as in Fig. 5, although some plants are installed with closely spaced pipe coils. By installing gravity-type units over the aisle, the periodic removal of frost is made much easier. Such locker room units are usually selected at a temperature difference of 15 to 20 F.

If forced air units are used to refrigerate the locker room, they should provide air distribution to all parts of the room. Ducts are sometimes necessary in large locker storage rooms. If ducts are not used, the velocity of cold air as it leaves the grille or distribution hood must be high enough to reach the farthest part of the room. **The space between top of the lockers and ceiling should be open and unobstructed.**

Forced air units for locker rooms should be selected for a smaller temperature difference than is used for gravity applications, usually 5 to 10 F.

A positive means of defrosting forced air units must be provided. Outside air, hot gas, water or electric defrosting have been successfully used. Defrosting may be controlled manually or automatically and must be scheduled by the operator on a regular daily basis.

Temperature control devices. An important requirement of the modern frozen food locker plant is that it be entirely automatic in respect to regulation of temperature. The condensing unit controls may be of the low pressure or thermostatic type. Temperature regulation in such systems is usually accomplished by controlling the running time of the condensing unit, and applying the proper controls to one or more evaporators.

When a single condensing unit is used for each zone of refrigeration, the low pressure type of control may be used. It will function satisfactorily for either low or normal temperature areas. **Low pressure control** is necessary where automatic defrosting of normal temperaure evaporators is desired.

If more than one temperature zone of refrigeration is connected to a condensing unit, it will be necessary to observe the usual rules for multiplex control. Evaporators in different temperature zones in a system of this kind usually operate at different suction pressures, and, therefore, evaporator regulator valves or thermostatically controlled solenoid valves will be required on all except the lowest temperature refrigerant circuit.

If the temperature variation between zones is only a few degrees, such as between a chill room at 35 F and a cure room at 40 F, it will usually be satisfactory to use an evaporator regulator valve or **snap action valve** in the suction line to the cure room evaporator. Some engineers install special controls in the freezer cabinet or room in order to prevent the cycling of the condensing unit during the handling of a heavy freezing load. This may be accomplished by a **manually operated switch** connected across the terminals of low pressure control, so that the operator has the option of closing the switch and causing the condensing unit to operate continuously until the freezing has been completed.

This function may also be handled on a semi-automatic basis if so desired, by having a special thermostatic control in the circuit instead of the manually operated switch just described. This special thermostatic control is provided with a flexible capillary tube between the switch mechanism and the bulb or operating element. The operating element may be inserted in a package of food which is being frozen and the control so adjusted that the condensing unit will operate continuously without cycling until the food has reached a predetermined low temperature (usually approximately 0 F).

If the refrigeration system is planned so that one condensing unit will handle both the freezer and the locker room evaporators, there are certain precautions which should be taken to prevent wide fluctuations in the temperature of the locker room. Such installations may be provided with a **suction line solenoid** valve with thermostatic control on the locker room evaporator. The thermostat should be adjusted to close the solenoid valve if the temperature of the locker room drops below a certain predetermined point. This is usually -3.5 to -4 F. This condition may be obtained during periods of heavy loading of the freezer. Under such conditions, the freezer may demand continuous operation of the condensing unit for several hours. Without the thermostatically controlled suction solenoid valve in the circuit, the locker room evaporators may continue to function and produce wide temperature variations.

For **liquid refrigerant control,** most engineers prefer thermostatic expansion valves for frozen food locker plant refrigeration systems. A few prefer expansion valves of the automatic type. Thermostatic control of the condensing unit is required, with automatic expansion valves. Most ammonia refrigeration systems used in frozen food locker plants are equipped with a low side float control which regulates the flow of liquid refrigerant to the evaporators. Evaporators are usually of the flooded type. Other control items for both low and

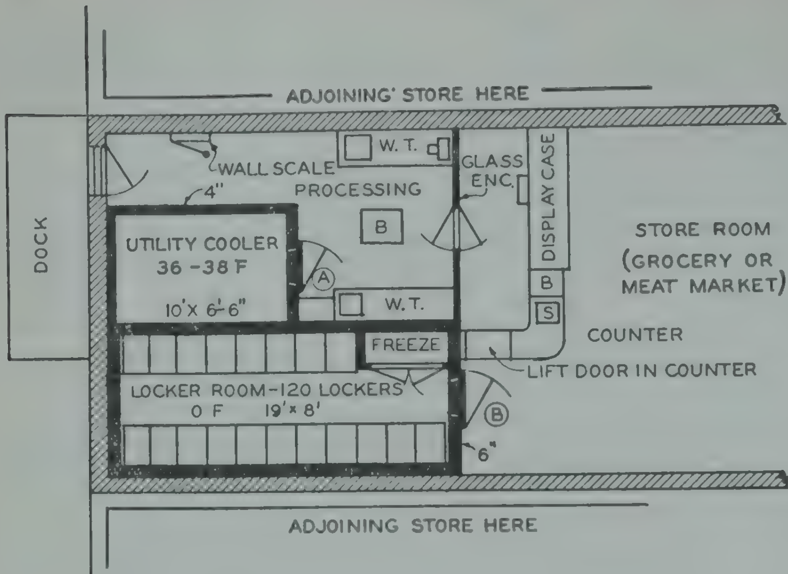

Fig. 7. Frozen Food Locker Plant Combined with Grocery and Meat Market. Plan A.

high pressure systems may be required—such as water regulating valves, high pressure cutouts, and modulating damper controls with forced air systems.

Many attempts have been made to standardize frozen food locker plants so that the plans and specifications for a given size would be available for several projects. This has been done to a certain degree as far as equipment is concerned, and, in some cases, many of the details of building construction have been similar. It is not likely that such a procedure will be carried out with any great number of plants, however, because each one differs in some respects from all others. The following examples A, B and C are, therefore, included here for reference purposes only.

Plan "A"—120 Lockers

Plan "A" (Fig. 7) provides for a small frozen food locker plant to be operated in connection with a grocery or meat market. This plant is typical of many that have been installed as an additional source of revenue to the store owner, as well as a convenience to the families in the community.

The general layout of a plant of this type and size should be made so as to best use the space available for both operator and store customers, most of whom may be expected to become locker patrons. It is usually best to locate the plant in the rear of the store, so that patrons may enter the front and pass through the store to get to their lockers. This helps the sale of other merchandise, especially to those who were not formerly regular store customers.

If the store is a small one, there will be times when it will be necessary for the operator to be in position to wait on customers in any part of the store. For this reason, the processing department should be so arranged that the operator can view any part of the store from where he is working. A glass partition around the processing room is suggested for this and for sanitary purposes.

A utility cooler, equipped with a double row of meat rails on each side, is required to handle the needs of the plant as well as those of the retail store. It is 10 ft × 6 ft-6 in. with an 8 ft-6 in. ceiling. The locker room is provided with 19 tiers of lockers, 6 high on the floor and with 3 tiers 2 high on top of the freezer cabinet. Door lockers are 17 in. high × 20 in. wide × 30 in. deep. Drawer lockers (2 lower ones) are 23 in. high × 20 in. wide × 30 in. deep. Allowing a minimum of 17 in. for ceiling plate evaporators plus 114 in. for lockers requires 10 ft-11 in. inside for ceiling height.

The floor is 19 ft × 8 ft, which allows sufficient floor space for the lockers, a freezer cabinet and a 34-in. aisle with 1-in. clearance allowed at back of lockers. The processing equipment need be little more

than for a small retail meat store, i.e., a power grinder, scales, cutting blocks, work tables, knives and other hand tools. Such items as trackage, power meat saws, smoke cabinets, lard rendering equipment and other special items may not be required. In selecting such equipment, it is best to consult with the operator who, if he is an experienced butcher or meat cutter, will know what he will need.

The **refrigeration requirements** are based on the following:

1. The plant capacity is based on 120 lockers, plus a 25 percent additional volume of retail meat sales.
2. Peak ambient conditions 95 F, except floor over unheated basement at 80 F for summer.
3. Water for condensing unit, 70 F maximum.
4. Electric service: 220 volt, 3 phase, 60-cycle, and 110 volt, 1 phase, 60-cycle.
5. Design temperatures: Chill room 35 F, locker room 0 F, freezing cabinet inside locker room, with shelf plates, −20 F.
6. Insulation: Chill room 4 in. corkboard; locker room 6 in. corkboard (or equivalent).

The **refrigeration load** is summarized as follows:

1. The **chill room**:

Heat leak and normal service, Btu per day	52,300
Product load at 2 lb per locker per day would equal 240 lb, with an addition of 25 percent for retail trade —300 lb. However, since an average weight of one beef carcass is at least 500 lb, this weight should be taken as the minimum product load for any chill room. Chill from 95 to 35 F, Btu	22,600
Total load, Btu per day	74,900
Hourly load based on 18-hr compressor running time, Btu	4,161

As automatic defrosting is required in the chill room compressor running time should not exceed 18 hr. The fan motor load may be added, after cooling unit is selected.

2. The **freezer cabinet**:

Product load, 2 lb per locker per day, reduced from 45 to 0 F, Btu	31,200
Hourly load, based on 24-hr compressor running time, Btu	1,300

Heat leak is disregarded, since the freezer cabinet is installed inside the locker room. Product load based on 2 lb per day per locker is the minimum allowable. Experience shows a heavier product load allowance may be advisable.

3. The **locker room**:

Heat leak plus light service only, Btu per day	162,060
Hourly load based on 24-hr compressor running time, Btu	6,753

Automatic defrosting is not required, and calculations are based on peak ambient; therefore, 24-hr compressor running time may be used for freezer and locker room.

Refrigeration equipment selection:

1. **Condensing units.** One unit is needed for chill room, with minimum capacity required of 4161 Btu per hr, plus fan motor load at refrigerant temperature of 18 F (15 F difference + 2° suction line drop; 35° room − 17° difference = 18° refrigerant).

A second unit to handle combined locker room and freezer load (6753 + 1300 = 8053 Btu per hr total). This unit should be selected at −22 F refrigerant temperature. (20 F difference + 2° suction line drop; 0 F locker room − 22° difference = −22 F refrigerant).

Either air-cooled or water-cooled units may be selected (condensing medium air at 80 F if condensing unit is in basement, at 95 F if not, or water at 70 F). By referring to a manufacturer's condensing unit capacity tables, the proper models or sizes may be specified for the above. For example, one manufacturer shows a capacity of 5900 Btu per hr for a ½-hp water-cooled unit at 18 F refrigerant and 70 F inlet water which might be used for the chill room; and another of 8450 Btu per hr for a 2-hp (3-phase) water-cooled unit at −22 F refrigerant and 70 F inlet water, which might be used for the locker room and freezer. (The

display case may be connected to the chill room condensing unit by selecting the unit with sufficient additional capacity for that purpose, and by adding the proper controls for this type of multiplex operation.) Total compressor horsepower, therefore, would be 2.5.

2. Cooling units. Gravity or forced air units may be used in the chill room. For this example, assume the forced air type is used. The temperature difference between the chill room and the refrigerant should be 10 to 15°. We find that $5900 \div 15 = 393$ Btu is the required basic rating (Btu per hr per degree difference) of the evaporator required to match the condensing unit. One should select a cooling unit having at least this capacity. The cooling unit selected from the manufacturer's tables has a basic rating of 400 Btu per hr per degree difference with a 1/75-hp fan motor, and a motor heat dissipation of 222 Btu per hr. As the fan is run continuously, the load from this source is added to heat leak, plus product load:

$$\frac{222 \text{ Btu per hr} \times 24 \text{ hr}}{18 \text{ (hr)}} = 296 \text{ Btu per hr}$$

296 Btu per hr (fan load) +4,161 Btu per hr (heat leak + product load) = 4,457 Btu per hr total, equaling the hourly capacity of the condensing unit selected. A thermostatic expansion valve is required.

Plates for the cabinet freezer may be selected from standard sizes. The number of square feet of freezing surface may be based on the number of lockers. One square foot for each five lockers is the accepted practice for small plants of this kind, $120 \div 5 = 24$ sq ft of plate needed—one side only. A plate 22×48 in. is standard, having 7.4 sq ft on one side. Therefore, $24 \div 7.4 = 3.2$ plates needed (make it 4). One thermostatic expansion valve is needed.

Overhead plates for the locker room may be selected from standard sizes. The rating may be obtained from manufacturer's data. Using figures published by one manufacturer, we may select plates for this project as follows:

$$\frac{6753}{2 \times 24 \times 20} = 7$$

The selection, therefore, from this size is seven plates, which may be assembled in one bank. The 12×84-in. plate might also be used. We find that:

$$\frac{6753}{2 \times 14 \times 20} = 12$$

The selection from this size is 12 plates assembled in 2 banks of 6 plates each. Either 144 or 84-in. plates may be used on this project, with the 84-in. selection having the advantage because of better refrigeration distribution above the 34-in. aisle. Each bank of plates will require one thermostatic expansion valve.

A fair estimate of the **operating cost** may be determined by calculating the water and power usage (from manufacturers' tables) on a 60 to 80 percent running time basis.

This type plant does not require a complicated **control** system. The condensing units may be equipped with low pressure control, since the cooling units have been equipped with thermostatic expansion valves. If fluctuations occur in locker room temperatures when a heavy load is put on the freezer, install a thermostatically controlled solenoid valve in the suction or liquid line to the locker room plates.

Plan "B"—355 Lockers

(Also see plan "B" alternate)

Floor Plan "B," **Fig. 8,** is for an average sized plant which may be operated as a separate business or as a complementary part of another business. A plant of this size is large enough to require the full time of an attendant, providing additional help may be available when needed during the peak season. Under average conditions, the operator of such a plant will have very little spare time for other responsibilities.

Facilities are provided in this layout for practically any normal service that may be needed in a frozen food locker plant, with the possible exception of slaughtering. Slaughtering facilities may be provided in a nearby location, at an out-of-town location, or may be done on the customer's premises.

This plant is laid out in such a way as to eliminate as much trucking and handling labor as possible. Chill and age rooms, for example, are accessible to the delivery platform in the rear, and the processing room is at the other end of the track. The main track runs straight through so that the use of turns and switches is reduced to a minimum. There is no insulation in the

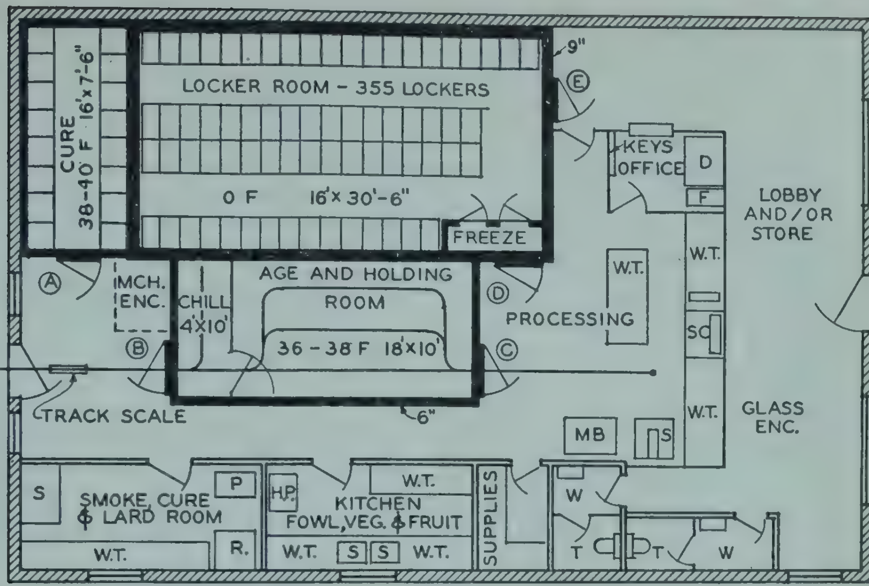

Fig. 8. Typical Frozen Food Locker Plant. Plan B.

partition between the chill room and the aging room. A free-swinging door is installed between these two rooms. Ceiling height is 9 ft. Four pounds per day per locker are used as a basis for the refrigeration load in the chill and aging rooms. This will take care of short-time holding for the cure room and leave sufficient capacity to take care of peak requirements for other refrigeration requirements.

The smoke, cure and lard work rooms are located in the rear near the refrigerated cured meat room. A small utility kitchen is provided for the handling of fowl, fruits and vegetables. This room may be used for preparation work by plant personnel or patrons, according to schedule. A supply room for paper and packaging materials, etc., is provided at a convenient location for the operator.

The refrigerated room for the storage of cured meats is shown with enough wooden bins ($24 \times 24 \times 18$ in.) to accommodate 80 or more customers. Barrels or casks for wet cure may be substituted for all or part of the bins as shown.

The locker room is provided with 355 lockers, and may be entered from the lobby. All patrons entering the locker room are in sight of the operator. Lockers for this room are selected with five in each tier, consisting of two lower drawer-type lockers 18 in. wide, 22 in. high and 30 in. deep, with three door-type lockers above $18 \times 18 \times 30$ in. An additional group of 10 door lockers is located above the freezer cabinet.

The freezer cabinet is located inside the locker room, and arrangements are provided for loading the freezer cabinets through a plug or utility-type door. The practice of placing foods to be frozen in the freezer immediately after packaging, eliminates delays and saves a certain amount of handling. The freezer cabinet may be provided with a lock so that it may be opened only by the operator when distributing the frozen foods from the freezer to the patrons' lockers. No facilities are provided in this layout for retail sales. Details of facilities for this purpose may be added if necessary.

The **refrigeration requirements** for this plant are based on the following:

1. Plant capacity, 355 lockers
2. Peak ambient conditions, 95 F
3. Water for condensing unit, 70 F
4. Electric service, 1-phase and 3-phase 110–220 volt 60-cycle
5. Design temperatures:
   Chill and aging rooms, 35 F
   Cure room, 40 F
   Locker room, 0 F
6. Insulation:
   Chill and aging rooms, 6 in. fill type
   Locker room, 9 in. fill type
7. Product loads:
   Chill room, 4 lb per locker per day
   Freezer, 2 lb per locker per day.

In order to select the refrigeration equip-

ment for this project, it is necessary to first prepare load calculations as follows:

	Btu per day	*Btu per hr*
1. Chill and age room	129,646	7,202
2. Cure room	63,357	3,520
3. Freezer	89,637	3,734
4. Locker room	251,561	10,481

Refrigeration equipment selection:

1. Condensing units. One unit may be used for chill, age and cure rooms combined (7202 Btu per hr + 3520 Btu per hr) = 10722 Btu per hr at a refrigerant temperature of 23 F.

A second unit may be selected for the locker room and freezer load combined (10,481 Btu per hr + 3734 Btu per hr) = 14,215 Btu per hr.

Since water at 70 F is available, refer to a manufacturer's tables and the condensing units may be selected for the above. Example: A 1-hp condensing unit with a capacity of 12,072 Btu per hr at 23 F refrigerant and 70 F inlet water, which might be used for the chill room and cure room load (10,722 Btu). Another condensing unit (3-hp) from the same tables has a capacity of 15,050 Btu per hr at −17 F refrigerant, and 70 F inlet water for the locker room and freezer load (14,215 Btu per hr). In this case, the condensing units required will have a total of 4 hp.

2. Evaporator selection is as follows:

Forced-air units may be used in the chill and aging rooms. Selecting 10 F temperature difference we find that $\frac{7202 \text{ Btu}}{10} = 720$ Btu is the required basic rating for both the age and chill room evaporators. This may be divided by 2, because approximately one-half of this load is the age room and one-half is chill room; this proportion may vary with different plants. $\frac{720}{2} = 360$ Btu basic rating for each evaporator. A thermostatic expansion valve should be used with each evaporator. A unit for the cure room is selected in the same manner. Cure room load, 3520 Btu ÷ 10 = 352 Btu. One manufacturer's tables show a unit at 400 basic rating with 1/40-hp fan motor, and an hourly fan motor heat dissipation of 222 Btu per hr, one of which will be used in the chill, age and cure rooms. $\frac{222 \times 24}{18} = 296$ Btu per hr fan motor load. $296 \times 3 = 888$ Btu per hr. Add this to heat leak and product load $10{,}722 + 888 = 11{,}610$ Btu per hr. Condensing unit selected at 12,072 Btu per hr has ample capacity to handle this additional load due to fan motors. An evaporator regulating valve should be used on the cure and age room evaporators, due to the variable load on the chill room and to hold the cure room at approx. 38 to 40 F.

Plates for the cabinet freezer may be selected from standard sizes. Basing the number of square feet of surface for freezing on the rule of 5 lockers per sq ft, we have $355 \div 5 = 71$ sq ft one side only. A plate 22×72 provides 11 sq ft. Therefore, $71 \div 11 = 6.4$ plates. The selection, therefore, would be 7 plates 22×72 in. These would fit in the space provided. Two thermostatic expansion valves are needed.

Overhead plates for the locker room may also be selected from standard sizes. Using one manufacturer's data, we find

$$\frac{10{,}481}{2 \times 24 \times 15} = 14.6$$

Thus 16 plates will be satisfactory. These plates may be arranged in four banks of four plates per bank. Plates should be spaced about 2 ft from each end of each aisle, and attached to ceiling hangers. One thermostatic expansion valve is required for each bank.

Plan "B" Alternate

On the 4th and 5th pages of this chapter reference is made to the use of low temperature blast type freezers to handle the refrigeration load of freezing and holding the locker room at 0°. As an example of how this may be handled see **Fig. 9.** This is the same locker room shown in Fig. 8 except that it is equipped with a blast freezer and locker room cooling unit as illustrated in Fig. 6. In this case, the locker room has been provided with two doors one for the patron to use when going to his locker, and the other at a convenient point for the operator of the plant, since he will want to take as few steps as possible when placing food in the freezing unit and when removing it to place in his patrons' lockers.

It will be noted that the blast freezer is placed near the wall. This is to facilitate defrosting which may be either manual or automatic.

The blast freezer should be so located

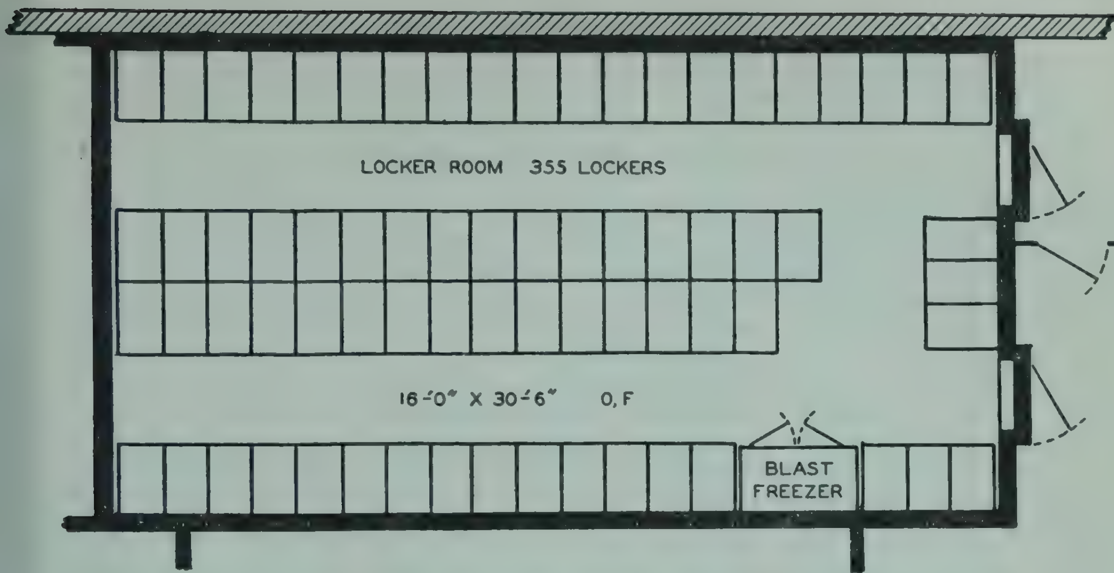

Fig. 9. Locker Room with Blast Freezer—See Plan "B" Alternate.

that good air distribution will be obtained to all parts of the room. Except in large locker rooms, ducts are usually unnecessary. The unit should be high enough to permit the air blast to pass between the tops of the lockers and the ceiling. A clear space of 12″ to 18″ is desirable for this purpose.

Load calculations are the same as for Plan "B" but the equipment selections may be made at a smaller temperature difference, 10° is a satisfactory figure and is used by most engineers. One manufacturer provides a unit with a capacity of 14,000 Btu's at 10° T.D. This will handle the load under consideration providing the compressor selected will deliver the necessary capacity at −10 F (Ref. temp at freezer) and approximately 2° allowance for line loss. The compressor may be selected at −12 F refrigerant temperature and 70° water for condensing.

Plan "C"—1008 Lockers

The plant layout shown in **Fig. 10** provides a locker room for 1008 lockers, a chill room, an aging room, a cure room, a freezer room, utility kitchen, processing room, lobby, office, cure and smoke work room, lard grinding and rendering room, supply room and shop. Toilets and wash rooms are provided also for employees, in the hall, and for customers, just off the lobby. If a heating plant is needed, it may be located in a small basement, or space may be provided in the rear by a rearrangement of the shop and lard room.

A plant of this size will require more floor space than is ordinarily found in a store room, and for this reason, a special building may be required. Parking space may be provided on the north side or in the rear. A driveway is needed on the south side and in the front, so that all incoming carcass meats and other foods can be brought to the dock on the south side where they are weighed, checked and passed on to the proper department for processing.

The building may be one-story with under-roof ventilation (to reduce heat load on room ceilings). Cement block, brick or other type of masonry construction is suggested. This plan may be easily altered to provide for either less or greater capacity by changing the length of the building and the principal rooms to correspond.

Patrons may enter the front lobby for the transaction of business or to visit the locker room. A display cabinet may be provided here to show special commercial frozen foods which may be for sale, or to show patrons how they may package some of their own foods.

The processing room where most of the work is done is in the front where the

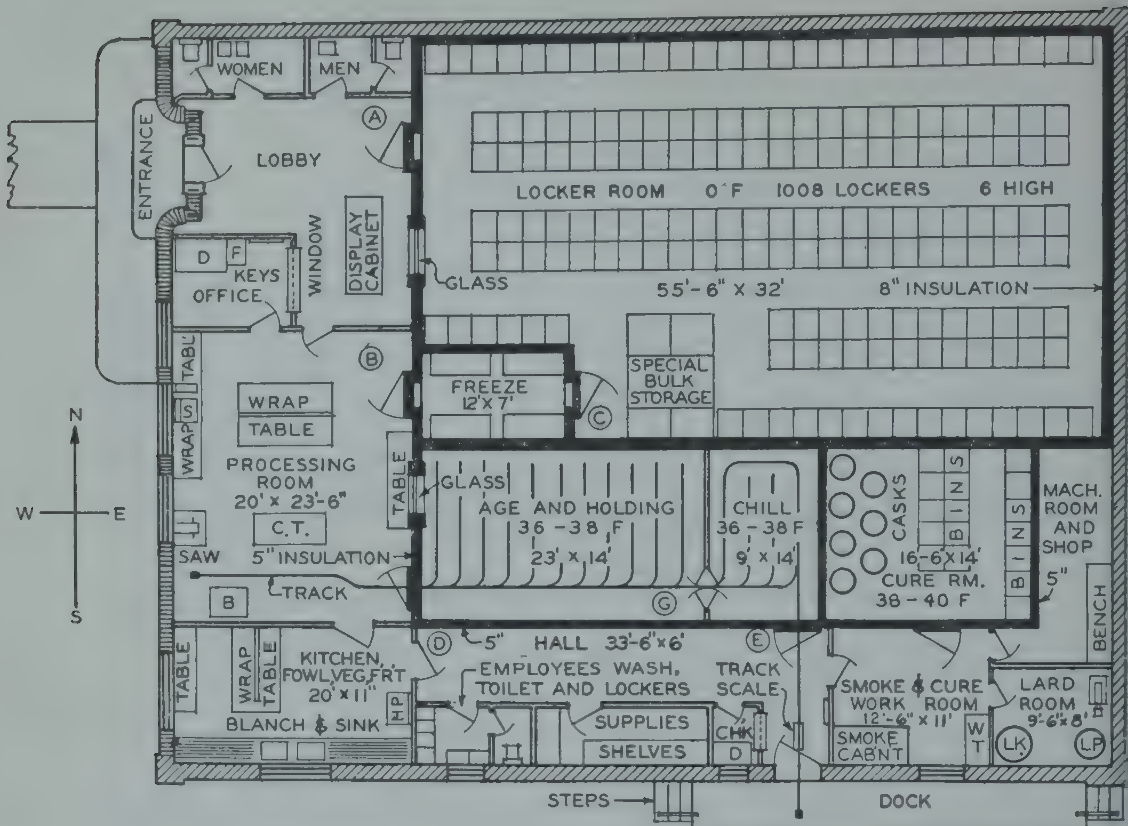

Fig. 10. Frozen Food Locker Plant. Plan C.

operator may keep most of the plant under observation and near the office where records may be easily referred to. Carcass meats are brought in on the track from the age and holding room for processing and placing in the freezer room nearby. Packaged foods from the kitchen can be conveniently and quickly transferred to the freezer.

The utility kitchen is large enough to accommodate blanching, cleaning and packaging of various items such as fowl, small game, fruits, vegetables and fish. Some operators like to schedule work in the kitchen so that different products are handled on different days.

The age and holding room where carcasses may be aged or held for the required length of time is convenient to the chill room and the processing room. An observation window is shown in the west wall of the age and holding room.

The smoking and curing department, as well as the lard rendering room, is in the back of the plant so as to keep odors from filtering through to the other rooms. The refrigerated room for cured meats is shown with both bins and casks. This room should be provided with the kind of equipment needed for the type of curing to be done, such as wet or dry, salt or sugar cure.

The freezer room is convenient for loading from the processing room and is provided with doors at each end. The freezer room is equipped with low temperature shelf plates for contact freezing, and with ceiling plates to handle the heat leakage into the room. All plates are operated at approximately 15 F below zero.

The locker room is arranged for efficient refrigeration. All insulated walls are shielded from sun effect. Heavy insulation of 8 in. is specified. All aisles are 36 in. wide and open at both ends to allow patrons free access to lockers. Lockers are six high in each tier. Sizes are as follows: Lower drawer lockers $24 \times 20 \times 30$ in., second and third drawers $24 \times 16 \times 30$ in. and the upper door lockers are $24 \times 15 \times 30$ in. This provides a selection of three sizes which should

accommodate practically all needs. An observation window is provided in the locker room wall next to the lobby. This window will provide light in the locker room in an emergency and will be looked upon with favor by most patrons.

As a basis for **load calculations,** we will assume the following conditions:

1. Insulation, 5 in. corkboard, or equal, on age and holding room, chill room and cure room, and 8 in. on locker room and freezer.
2. Peak ambient, 95 F except that floor is 75 F.
3. Ceiling height, 9 ft 6 in. except in freezer which is 7 ft 6 in. inside.
4. Chill room is to handle 4 lb per locker per day.
5. Age and holding room has no product load.
6. Cure room will handle 1 lb per locker per day.
7. Freezer will handle 2 lb per locker per day.
8. Locker room will have no product load.
9. Design temperatures are: Chill room, age and holding room 34 to 36 F (average 35 F) cure room 38 to 40 F with thermostatic control and solenoid or evaporator regulating valve on cure room to provide for adjustment to 38 to 40 F.
10. Freezer plates operate at −15 F and locker room operates at 0 F. Water-cooled condensing units will be used as follows:
    1 on chill, cure and age and holding room
    1 on freezer
    1 on locker room.
11. Water for condensing units at 70 F.
12. Electric service, 60-cycle, 110–220-volt, single-phase, and 220-volt, 3-phase.

The refrigeration load and unit selection may be determined by the foregoing methods.

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If you searched this chapter for something which was not found in it, please let the editors know.

37. COMMERCIAL REFRIGERATORS

THE term **commercial refrigerator** is applied to factory-built portable refrigerated enclosures of the type used by retail food stores, restaurants, hotels and institutions for storing, displaying or dispensing perishable foods or other commodities. Generally speaking, any type of refrigerated fixture, cabinet or room so constructed as to be readily removed or disassembled is a commercial refrigerator. Principal types and their characteristics are as follows:

Display Cases

A display case is a combination storage and display cabinet or counter designed for the retail merchandising of meats, fish, dairy products or other highly perishable foods. Eye appeal to the shopper is an important consideration. As large an area of the front or display side as possible consists of a unitized glazed panel, using two to five courses of high quality glass, slanted at a suitable visual angle. Various methods are employed for preventing the collection of moisture between the glass sections and minimizing efflorescence and sweating. In recent years glass manufacturers have developed a prefabricated glazing unit for display case panels, service doors, etc. Courses of high quality glass, with proper air space at low dew point between them, are hermetically sealed in an integral unit at the factory, and furnished in the exact size to fit the particular opening. Complete elimination of dirt and moisture is claimed.

A display case incorporating a glazed front panel, without access to the interior except through service doors, usually placed in the rear, is known as a closed or service case. Display cases which, through the elimination of the sealed-in glass front panels, afford access from the front or top are known as open or self-service cases. The latter are fully described later in this chapter. The descriptive details immediately following apply more specifically to closed type cases.

Shelves must be so placed in relation to the horizontal plane that the contents of all platters or trays are visible to the standing shopper. The interior wall is finished either in porcelain, stainless steel or synthetic enamel. Bottoms are constructed of copper, galvanized iron, porcelain or other rust-resisting metal, properly sloped to the drain connection.

Exterior finish, usually white porcelain, stainless steel or synthetic enamel, together

PAUL H. SULLIVAN, Author Chapter 37. Born 6/16/02 in Attica, Indiana. Educated at University of Illinois, BS, 1923.
Associate Editor textbook, "Trade Association Management"; lecturer and author of various articles and pamphlets on commercial refrigeration, business economics, and trade association management; author Chapter 34, 1946 Applications Volume, ASRE Data Books.
Member, American Trade Association Executives; Trade Association Executive Forum of Chicago; Board of Managers, National Institute for Commercial and Trade Organization Executives, Northwestern University.
Executive Secretary, Commercial Refrigerator Manufacturers Association, Chicago, 1933 to date.

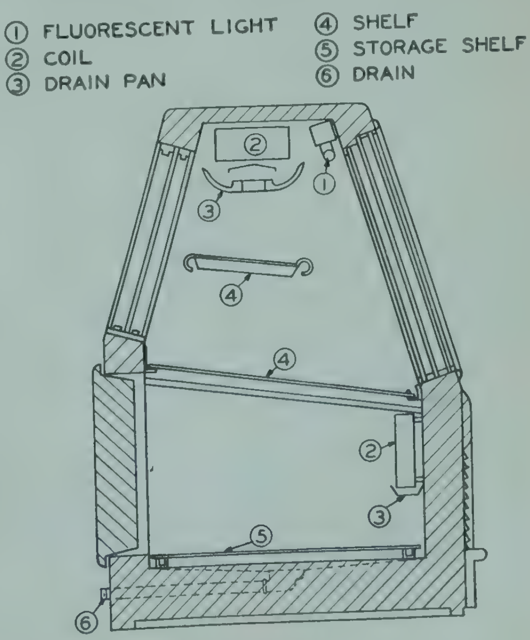


Fig. 1. Double Duty Case.

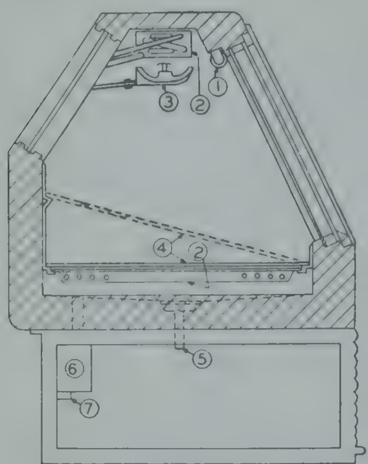


Fig. 2a. Top Display or Single Duty Service Case.

with showcase illumination, carries out the primary purpose of effective eye and sales appeal. The lighting, if of the incandescent type, is installed outside the case, below the top front edge, with a covering shield or baffle to prevent eye-glare, and eliminate shadows within the case. In the last few years, the development of fluorescent or neon-type lighting systems has led to a widespread use of this type of illumination, mounted on the inside of the case, usually just below or adjacent to the top evaporator drip pan or baffle. The great majority of display cases being manufactured today utilize this method of illumination, for which a number of advantages is claimec such as glareless visibility and minimur heat input.

The back, or working side of the case, i equipped with sliding or lift-type multipl glazed doors of hard rubber composition o plastic material, allowing easy access. I double duty cases, the lower refrigerate storage compartment is equipped wit solid hinged doors. One or more wrappin shelves, and a scale stand, may be mounte at convenient points on the back of th case.

Cases incorporating a so-called endles construction feature are becoming increas ingly popular with larger food stores an super-markets. Two or more cases ar joined to form a continuous unit, withou partitions at the point or points where th individual sections are joined together. Se **Fig. 2b.**

Double duty case. In this type of refrig erated display case both the upper and th lower or "blind" section are refrigerated thus providing substantial space for bul storage and display as in **Fig. 1.** These sec tions may or may not be separated by a insulated partition. In the smaller, sel contained models, a portion of this bul storage compartment may be walled off t enclose the condensing unit, although i many self-contained models the machin compartment is attached to the end of th case.

Single duty case. The upper display sec tion only is refrigerated, the base sectio

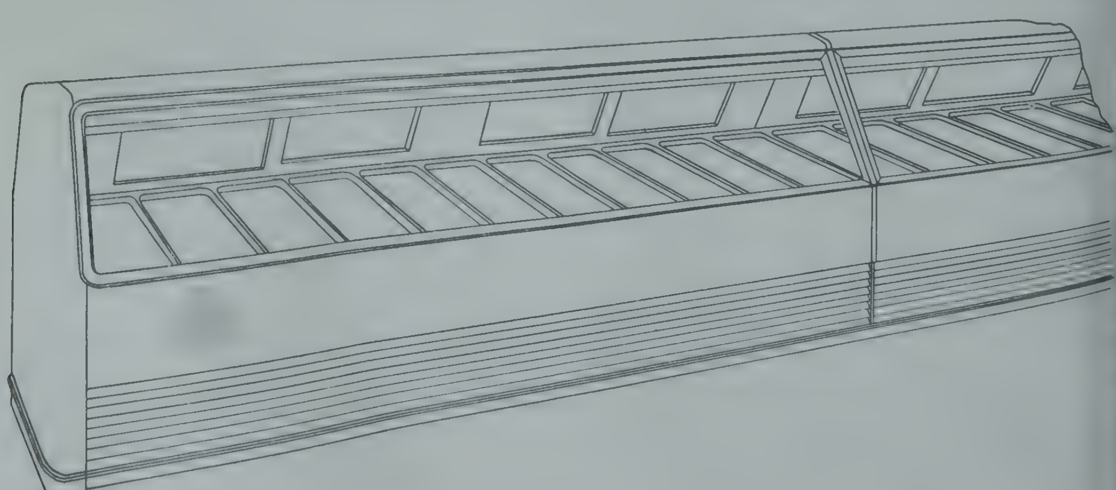


Fig. 2b. Continuous Type Single Duty Case.

eing left open at the back, as in **Fig. 2a.** :hain stores, super-markets and other re-ail stores with a fast turnover find the ingle duty case especially adaptable, as aily warehouse deliveries or the avail-bility of other bulk storage facilities in he store obviate the need for extra storage 1 the case.

With the development of the super-mar-et and a stronger trend toward moderni-ation in display equipment, the single uty or top display case has been stream-ned into a continuous unit. Manufactured vith or without ends, it can be joined to-ether to provide a continuous display nany feet in length.

Special designs. The refrigerated display ase idea, as originally and most exten-ively applied to the meat counter, has een extended in a variety of directions. Among these special applications are:

Full-vision. This type of case employs most of or the entire interior space for display as in **Fig. 3.** The glazed panel is

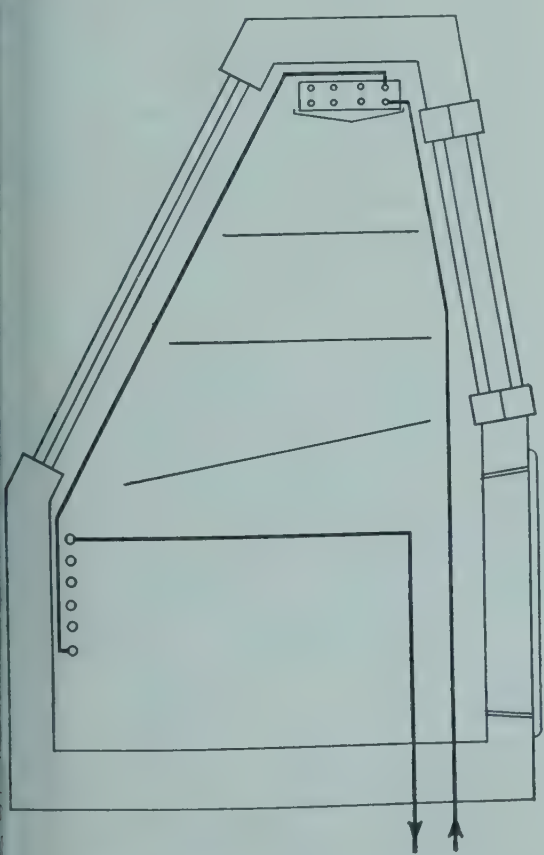


Fig. 3. Full-Vision Delicatessen Case.

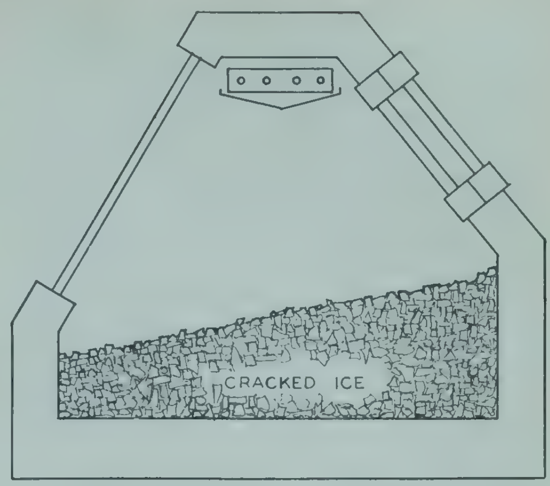


Fig. 4. Fish Display Case with Top Evaporator.

extended as close to the base as is practicable, the additional space being used to hold one or more extra shelves. Cases employing the "full vision" feature are most popular among delicatessens and specialty food markets.

Fish and poultry units are constructed similarly to the standard single duty case except that bottom of the display compartment consists of partitioned metal bins for cracked ice, with a drain connection. An overhead coil is installed to reduce ice meltage; see **Fig. 4.**

Frozen foods. Except for the more recently developed self-service frozen foods display case, frozen foods storage and dispensing cabinets are adapted from the ice cream cabinet. Some have made use of sliding glazed lids. The advantage of display has been sought in several successful case designs. The glazed display panel was usually kept small so that as much of the refrigerated space as possible may be utilized for bulk storage.

Self-Service Display Cases. Open-type or self-service cases are designed primarily for more effective display to increase impulse buying. They also permit the handling of larger volumes of merchandise, which is pre-packaged in cellophane or pliofilm in a selection of sizes or weights to meet the shopper's requirements, and labeled with the price and weight of each package. This type of display case is designed to be used as a single unit or in multiples to make a con-

tinuous display, when the endless type of construction is employed, as with conventional style closed display cases.

Self-service cases are widely used for merchandising a variety of perishable foods, such as delicatessen, cheese and dairy products, fresh red meats, luncheon meats, fruits and vegetables, and frozen foods. There are two methods employed in the design of the refrigeration system of the normal temperature case; one using gravity air circulation, with low velocity air movement, and the other using forced air convection supplied by blower coils. In the latter method, the air is drawn or forced through fin coils and distributed to the display areas through ducts.

The standard low pressure control alone can be used on open-type self-service cases, where temperatures are not below 35 F as recommended by Table 2. For open-type self-service cases used to display fresh red meats and luncheon meats, temperatures below 35 F are sometimes requested. Such temperatures cannot be obtained on a defrost cycle with the low pressure control alone. Some means of positive defrosting must be employed to obtain a satisfactory defrost cycle. The time clock or relay device is set for two or more defrost-

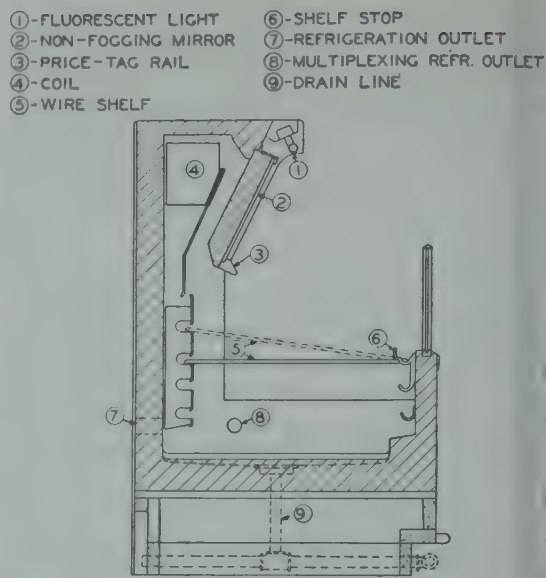


Fig. 5. Single Duty Open-Type Self-Service Case

ing periods, depending on numerous factors. When temperatures below 35 F are used, considerable experimentation with controls may be required to determine the number and duration of off periods per day for the individual installation. Seasonal weather changes may also require resetting the defrost schedule. Proper arrangement of products displayed is also essential to the proper performance of this type of equipment.

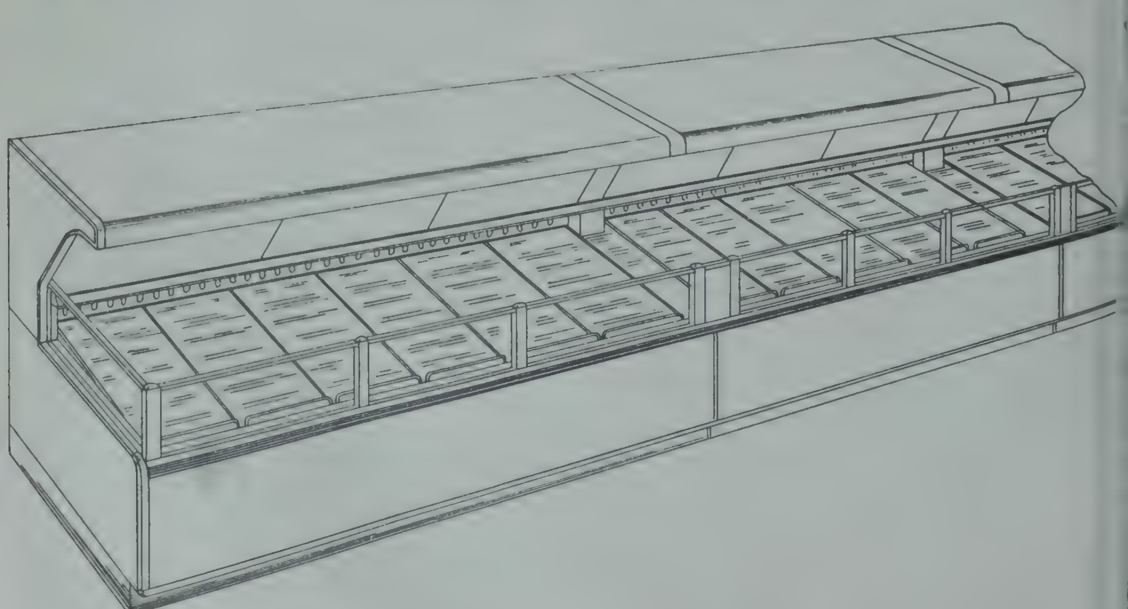


Fig. 5a. Continuous Open-Type Single Duty Self-Service Case.

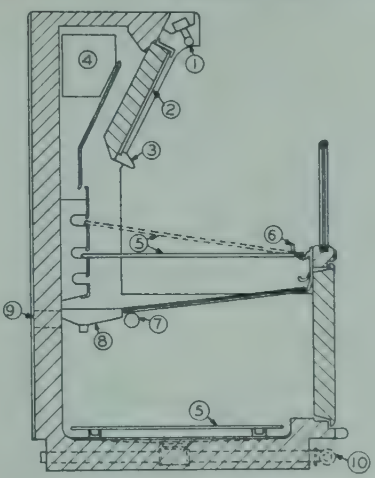


Fig. 6. Double Duty Open-Type Self-Service Case.

Strip heaters may also be employed to prevent sweating on price tags and mirrors.

Fig. 5 shows a cross-section of a Single Duty Self-Service Case, fabricated with ends for installation as a single unit. This type of case is also made without ends for continuous display, as shown in **Fig. 5a. Fig. 6** is a cross-section of the Double Duty Self-Service Case with the additional storage facilities in the bottom section. This case is fabricated with ends for single installation, and without ends for continuous display, as shown in **Fig. 6a.**

Fig. 6b shows a cross-section of a self-service display case for frozen foods or ice cream. It is manufactured in shorter lengths (six or seven feet) as self-contained units, or in longer lengths for remote installation. The low temperatures required to maintain frozen foods or ice cream in a salable condition require adequate coil surface, and positive control of air circulation. This may be accomplished by using an electrically defrosted finned coil in the superstructure to absorb the heat and moisture from the recirculated air, and plate coils in the bottom section to maintain the low temperatures required. **Fig. 6c** is a cross-section of a self-service display case for frozen foods, with a forced air circulating system. The defrosting of the low temperature plates is usually accomplished by scraping off the accumulation of frost when it becomes too heavy. Another method is through the use of removable metal sheathes or envelopes fitted to the plates. These may be removed and cleaned whenever the need is apparent.

Fresh fruits and vegetables. Refrigerated display-storage fixtures for these products are a comparatively recent development. Such equipment should eventually displace to a large extent the practice of displaying fruit and produce in open, non-refrigerated racks, or under water sprays. The vegetable case is primarily a display and dispensing unit,

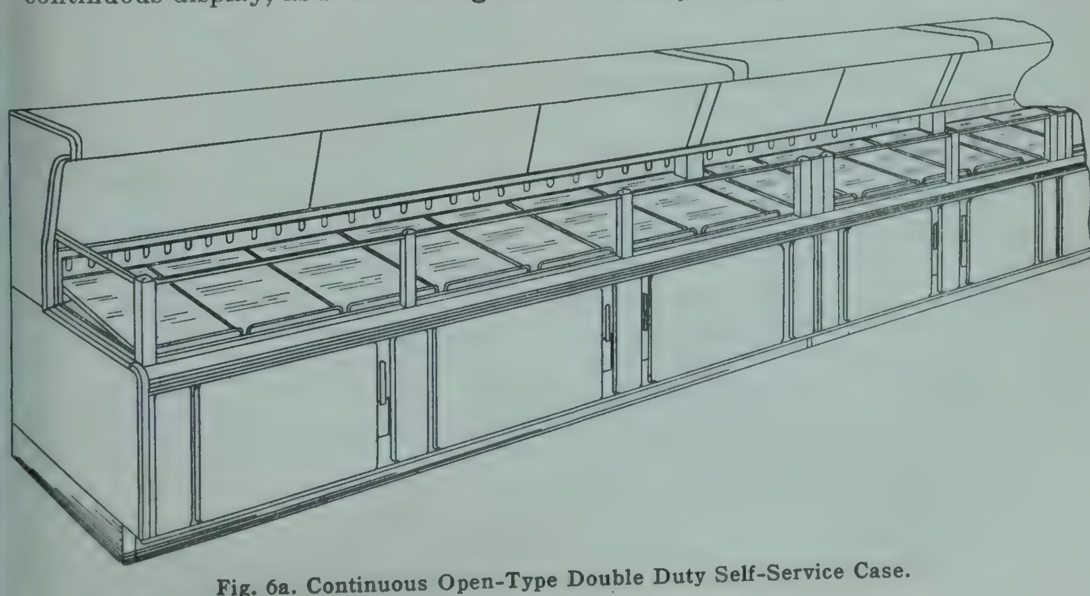


Fig. 6a. Continuous Open-Type Double Duty Self-Service Case.

and, therefore, is designed in keeping with other refrigerated display fixtures. There are two principal styles. In open models, the produce is arranged on racks or in bins, with entirely open front so that customers can serve themselves. Effective refrigeration is accomplished through cold wells, coils and baffles; see Fig. 6. Forced air circulation has also been successfully employed for keeping a stream of chilled air moving over the exposed surface.

In the closed type, the display section is fully enclosed, with large glazed doors occupying the display area, as in Fig. 7. Both single and double duty models are offered. Both open and closed styles are made in standard lengths, ranging from 6 to 12 ft long. Exterior surfaces are usually porcelain enameled steel. Refrigeration requirements are similar to those for meat display cases.

Wall or dairy refrigerators are cabinets similar in design and construction to the reach-in refrigerator (Fig. 7) but made in larger sizes and intended as display or self-service fixtures in retail food stores. They are most commonly used for displaying and dispensing packaged or preweighed food items supplemental to those handled in the meat case, such as dairy goods, bacon, cheese, milk, butter, yeast, cold meats. A typical wall cabinet consists of three full-length compartments, each having two or more glazed sliding service doors.

Refrigeration of cases. Display cases are usually refrigerated mechanically in one of the following ways: (1) by low side float type flooded evaporators (now practically obsolete); (2) by expansion valve evaporators. The latter are usually applied as follows: (a) By diffusion evaporators made up of lengths of tubing placed under shelves; (b) by a finned evaporator in the top and one or more diffusion or finned evaporators in the storage compartment; (c) by any of these in combination with cold plates; or (d) by forced air circulators or "blower coils." The latter method is of comparatively recent usage. Where properly designed and applied results are quite satisfactory.

As the great majority of cases manufactured are equipped with the proper evaporators, valves and controls at the factory, aside from selecting and connecting the condensing unit properly, there is no refrigeration problem for the installer to overcome except to make the necessary adjustments during the running-in period.

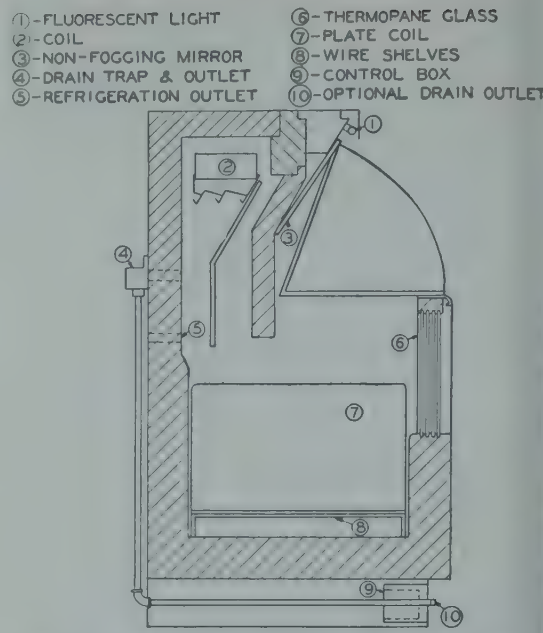


Fig. 6b. Open-Type Self-Service Frozen Food Display Case, with Plate Coils and Finned Coil.

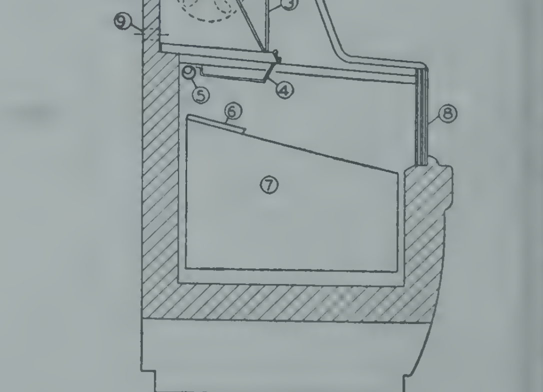


Fig. 6c. Open-Type Self-Service Frozen Food Case, with Blower and Plate Coils.

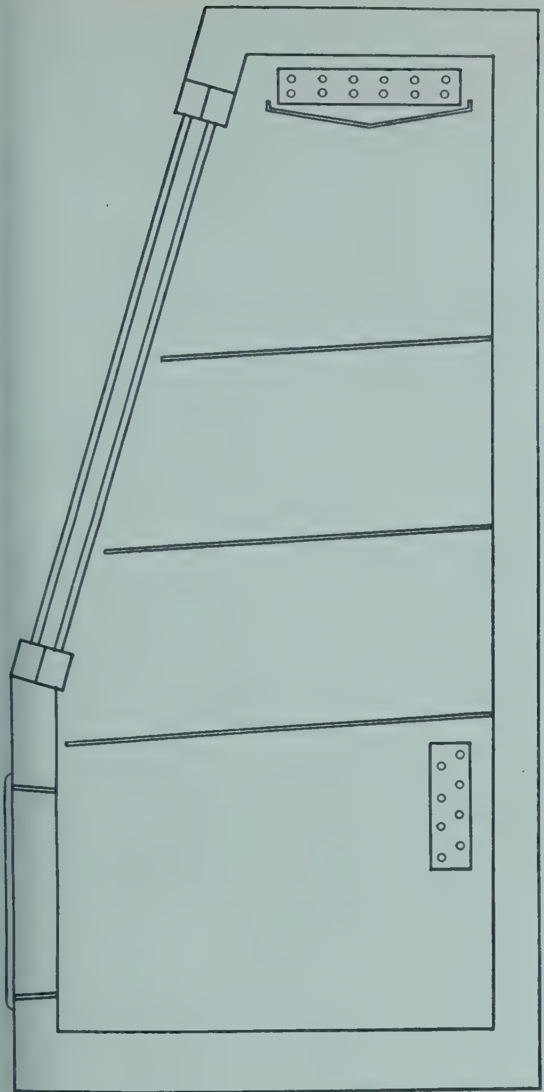


Fig. 7. Wall or Dairy Refrigerator.

Limitations of Display Cases

Modern merchandising of foods requires and stresses display. The refrigerated display case places the merchandise on view to the customer to the best advantage and then provides as much protection by refrigeration as the individual case design will permit. Food preservation conditions comparable to those in a walk-in cooler cannot be maintained. The time merchandise can be held in a display case at its best condition is limited. In other words, **the display case is primarily a display fixture.** Refrigeration results obtainable are limited by compromises to assure maximum display.

The type of case chosen is dictated primarily by the turnover of perishable merchandise in the store. Large busy urban and suburban markets with fast turnover of perishables can use the open-type display cases to good advantage. The small country or neighborhood store with slow turn-over should use the closed type of cases. Stores with rapid turnover will do well to use the top display types, with walk-in coolers for bulk storage. Small stores with slow turnover and unable to invest in walk-in coolers, should use the double duty case where the lower portion supplies some bulk storage.

The physical shape and dimensions of most cases are such that it is impossible to install sufficient coil surface to provide the ideal temperature and moisture conditions required for the optimum storage of perishables. The enforced shortage of coil surface may also create defrosting problems, particularly if attempts are made to operate the case at too-low temperatures. The effect of light on some perishables shortens their display life at optimum appearance. The open types of display fixtures are materially affected by the temperature, humidity and movement of the surrounding air. Therefore, they are even more difficult to refrigerate and control than the closed cases. Optimum salable appearance of meat products can best be obtained by using any display case for display during the day and returning the products to the cooler at night. Even then, only a few days of display life can be expected before the merchandise shows signs of deteriorating in appearance even though it still may be safe to eat. Package meats are often allowed to remain in the open type case overnight as a matter of convenience, resulting in some sacrifice of salability. Meat should not be left in display cases over weekends. Tables 1 and 2 have been prepared from practical field experience and laboratory tests with these facts in mind.

Typical specifications. Cases of both the double and single duty type are made in standard lengths, so that a single unit or a combination of units may be adapted to the user's particular requirements. Lengths of 6, 8, 10, 12, and 16 ft are most typical with a manufacturer offering a complete

line. Following are general specifications applicable to a 10 ft double duty case:

Dimensions: Depth 36 in.; height 50 in.; length 120 in. (OD).
Top Section: Four glazed sliding doors, $16\frac{1}{2}$ in.$\times 20\frac{3}{4}$ in.; three thicknesses of glass.
Bottom Section: 2 solid doors, 19×27 in.
Insulation: 3 in. thick.
Illumination: Ten 25-watt tubular lamps for display compartment; two 25-watt lamps in storage section, or interior cold-cathode or fluorescent lighting.
Display Compartment: 112 in. wide $\times$29 in. deep.
Capacity: 66 cu ft, gross, including bottom section.
Shelf Area: 50.3 sq in.
Refrigeration: $\frac{1}{3}$ hp, for remote installations. 3 in.$\times$6 in. fin coil in top section; $1\frac{5}{8}$ in. $\times$13 in. fin coil in storage compartment. Where specifically designed for such applications, blower coils may be used.

Table 1 may be used to compute the refrigeration load for selection of refrigeration equipment to operate cases of both the conventional and self-service types. The footnotes give instructions for its use, a typical example following: To select equipment for three 10-ft single duty top display meat cases, 3-in. insulation, three glasses (as in Fig. 2) to be located in a very busy super-market. Assume the maximum atmospheric temp 100 F, and maximum water temp 80 F.

1. Determine operating temperature differential at 100 F ambient, minimum case temp 38 F = 62 F.
2. Select refrigeration load factor, from col. 6 and footnotes of Table 1, for extra heavy service and specified type of case = 76 Btu per day per °F temp difference per ft of length of case.
3. Compute daily total load—76 Btu $\times$ 62 F difference $\times$ 30 ft of case = 141,360 Btu per day.
4. Assume maximum running time of 18 hr per day to secure automatic defrosting of evaporators (see notes, Table 1).
5. Compute hourly condensing unit capacity required. Since all three cases are similar and will be operated at same temperature and under similar service operating conditions, they may be put on one condensing unit. 141,360 Btu/18 = 7853 Btu per hr.
6. Select condensing unit from col. 4 average operating suction temperature for specified type of case = 20 F. A unit developing a minimum of 7853 Btu per hr at 20 F suction temperature and 80 F condensing water temperature (or 100 F condensing air), will be suitable. Most 1-hp condensing units will meet these requirements.
7. For temperature control use low pressure switch set for automatic defrosting—approximate settings with Freon-12, 35 lb per sq in. cut-in and 16 lb per sq in. cut-out.
8. Determine expansion valve requirements and other installation and operating characteristics; see footnotes of Table 1.

Walk-In Coolers

The **portable walk-in** type of market cooler or storage room is a factory-made product, as distinguished from coolers of the built-in type. Construction is sectional, the top, floor and walls being manufactured as separate components shipped "knocked down" to the user and set up on the job. Each section consists of a framework of wood, steel, or wood and steel, with interior ceiling, walls and floor of odorless woods such as fir, spruce or maple, pressed wood or of steel. Exterior may be wood or metal.

Coolers are equipped with one or more walk-in doors, to give the operator access; some also have smaller service doors. If of the window type, to admit light or provide a display feature, such service doors are glazed with multiple lights of glass much as in a display case; see **Figs. 8 and 8a**. Combination storage and display coolers employing the self-service feature are also being manufactured. In such coolers glazed sliding doors are mounted in the display section; see Fig. 8a. Where display is not needed, service doors are of solid construction. Interior equipment, if intended for meat storage, consists of meat rails and hooks, shelves and other such devices for hanging or arranging the contents.

In addition to their use for bulk meat storage, walk-in coolers of identical or similar design and construction are supplied for a variety of purposes, as, for example, combination low and normal temperature storage, the storage of fresh vegetables; for bulk frosted food storage; brea

1 Type of case	2 Construction		3 Type of evaporators*	4 Average refrign. temp °F	5 Average case temp °F†	6 Refrign. load factor‡ following types serv.		
	Insulation thickness	Glasses				Normal	Heavy	Extra heavy
Fig. 1—Double Duty	3½″	2–3	T-Fin Coil B-Fin Coil	20 F	38 F	76	84	91
Fig. 1b—Double Duty Self-Contained	3½″	2–3	T-Fin Coil B-Fin Coil	20 F	38 F	76	84	91
Fig. 2—Single Duty	3½″	2–3	T-Fin Coil B-Bare Tube	20 F	38 F	57	63	76
Fig. 2b—Single Duty Continuous	3½″	2–3	T-Fin Coil B-Bare Tube	20 F	38 F	57	63	76
Fig. 3—Full-Vision	3″	2–3	T-Fin Coil B-Fin Coil	18 F	40 F	102	114	124
Fig. 4—Fish Case	3½″	2–3	T-Fin Coil B-Ice Pan	18 F	35 F	50	56	59
Fig. 5—Single Duty Self-Service	3½″	2	T-Fin Coil	10 F	35 F	144	173	200
Fig. 5a—Single Duty Self-Service Continuous	3½″	2	T-Fin Coil	10 F	35 F	144	173	200
Fig. 6—Double Duty Self-Service	3½″	2	T-Fin Coil	10 F	35 F	144	173	200
Fig. 6a—Double Duty Self-Service Continuous	3½″	2	T-Fin Coil	10 F	35 F	144	173	200
Fig. 6b—Self Service Frozen Food	5″	4	T-Fin Coil B-Plates	−35 F	−5 F	120	132	145
Fig. 6c—Self Service Frozen Food Forced Air	5″	4	Fin Coil & Fan	−35 F	−5 F	136	141	166
Fig. 8—Walk-In Cooler	**	**	Forced Air Gravity	24–27 14–18	36 36	** **	** **	** **
Fig. 9—Reach-In Refrigerator	**	**	Forced Air Gravity	24–27 14–18	36 36	** **	** **	** **

* These will vary with different manufacturers. Evaporator length should be about 6 in. less than interior of case to allow for suction and liquid line connections. Finned types shown have ½-in. fin spacing and ⅝-in. tubing. Diffusion types are plain ⅝-in. tubing without fins. T indicates top evaporator; B indicates bottom evaporator. Evaporators must be so installed with relation to drip pans that free air circulation is obtained. Cases must be loaded by user so that air circulation is not interfered with.

† Use this temperature for determining refrigeration load. Temperatures will vary at different points in cases due to variable circulation and details of construction. Table 2 gives typical ranges.

‡ Load factor is given in Btu. per day, per °F difference between ambient and minimum case temperatures per foot of exterior case length. To compute refrigeration load per day multiply proper load factor by case length by temperature difference between maximum ambient and average case temperature from col. 5. To select proper load factor: Normal service in small market; Heavy service in busy market; Extra heavy service in very busy market. Load factors given are based on first grade fixture construction; in cheaper types of construction they may run much higher.

Condensing units should be applied to operate not more than 18 hr per day for maximum load. To compute required hourly condensing unit capacity, divide daily load determined as above by desired hours running time.

Use low pressure switch for temperature control. Adjust so that evaporators will defrost automatically. Approximate settings cut in at 33 to 36 F refrigerant temperature, and cut out at 3 or 4 degrees below average refrigerant temperature shown in col. 4. Make final adjustments to suit individual installation. Thermostat control will usually require manual defrosting of evaporators.

Use two thermostatic expansion valves (one on each section), on all double duty cases with insulated partitions. Use two expansion valves on all cases 14 ft or longer. Use one expansion valve on all other applications, expanding first through the top evaporator, following through the lower evaporator. Use drier loop or heat interchanger on last finned type evaporator before the suction line. Clamp expansion valve bulb on next to last tube of diffusion evaporator, or ahead of drier loop or heat interchanger on finned evaporator applications.

** For calculation of loads, see Chap. 19, 1949 Basic Vol., ASRE Data Books.

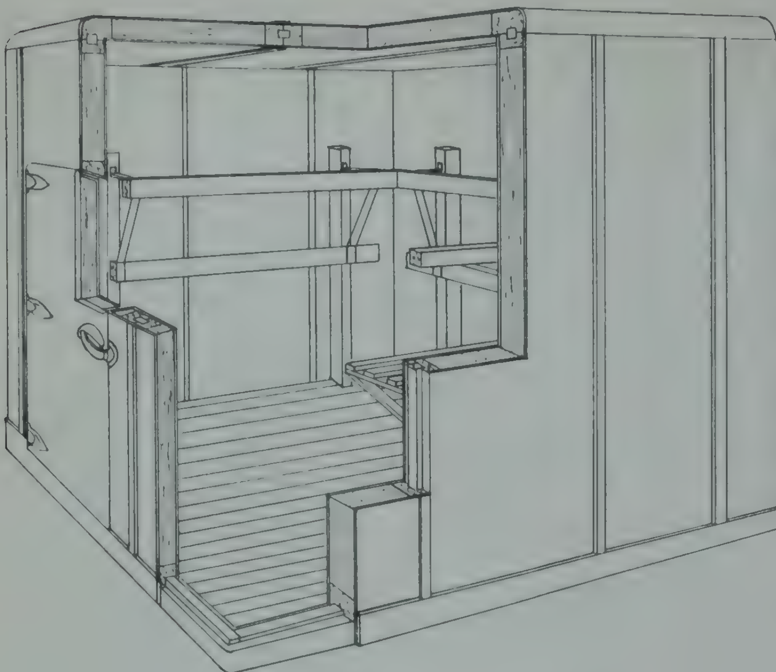


Fig. 8. Conventional Walk-In Cooler.

and pastry doughs; beer, wine and bottled goods; for flowers or wherever refrigerated storage greater than that provided by a smaller cabinet or fixture is needed. Refrigeration requirements will depend, of course, upon the nature of the product to be handled and conditions of operation.

In the last few years, a form of cooler design which allows the usable space to be expanded by simply adding extra sections has been successfully developed by various manufacturers. Of course, when the size is thus increased the refrigeration requirement must be revised accordingly. Constructed of either wood or steel, this unitized method allows a much greater flexibility in meeting individual users' needs without sacrificing production-line methods. Impetus was given this development by its adoption for use by the armed services, in World War II.

Refrigeration of coolers. In the mechanically refrigerated cooler, the selection of evaporators depends upon physical limitations, such as ceiling heights, and upon the storage requirements, together with the location of the cooler in reference to such heat-producing sources as cooking equipment, baking ovens, and the like. Thus each cooler installatio must be carefully eng neered.

Circulation is prime importance b cause of the amount air to be moved, an the multiplicity of su faces, angles, corner etc., over which th cooled air must b passed. Baffles an cooling unit decks mu be so placed as to a sure adequate a movement to or fro all parts of the cooler.

Where normal hea room is reduced b cause of the low heig of the ceiling in th structure housing th cooler, evaporators a installed at the sides ends, imposing pro

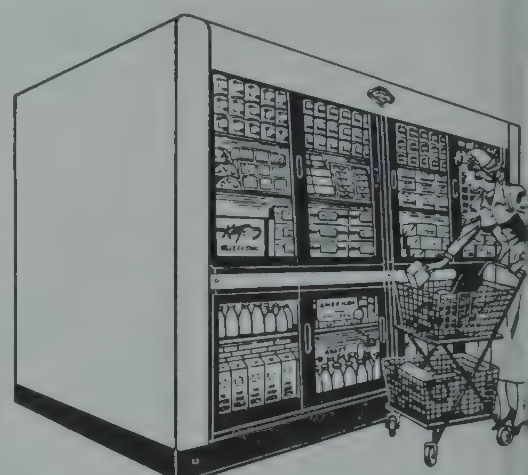


Fig. 8a. Reach-In Refrigerator with Glazed Doors.

lems not encountered with the usual ove head installation. Because of the difficul in such instances of preventing a zo of warmer air from collecting in the upp part of the cooler, the trend in recent yea has been toward the use of forced air circ lating cooling units. When such units a employed, care must be exercised to s that air movement is not too rapid a

that direct blasts of air from the cooling units do not strike the products in storage.

Typical specifications. Following are typical specifications covering a standard 10 ft × 8 ft market cooler for fresh meats, using finned coils.

Body Measurements: Length 120 in.; depth 96 in.; height 114 in.

Number of Coil Spaces: 2—Length 110 in.; width $26\frac{3}{4}$ in.; height 10 in.

Capacity: 568.4 cu ft

Construction: Exterior is porcelain on steel except on top and back. Interior is of odorless wood, shellacked. Floor of hardwood or metal. Walls 5 in. thick, insulated with 3 in. of corkboard or equivalent. One walk-in door at end, and three triple-glazed service doors in front. Interior equipped with meat rails and hooks. Bronze hardware on service doors; ball-bearings on entrance door. Each wall section, top and floor made as separate units, fastened together by means of bolts or pods.

Refrigeration Equipment: For operation at 100 F, ambient, heavy service, and 36 F cooler temperature use $\frac{3}{4}$-hp air or water-cooled compressor; two fin-type evaporators, 12 in. wide by 7 in high and 96 in. long; eight $\frac{3}{4}$-in. tubes, $\frac{1}{2}$-in. fin spacing; two thermostatic expansion valves.

Reach-In Refrigerators

This is one of the most adaptable types of commercial refrigerator. It is most widely used as a storage and display fixture by food handlers and in grocery and other food stores. The reach-in refrigerator or service cabinet also finds general use for storage and cooling purposes in restaurants, hotels, hospitals, institutions, and taverns, etc., where there is need for greater capacity than afforded by the household refrigerator (see Fig. 9). However, far from being an oversize household refrigerator, the reach-in is designed and constructed to

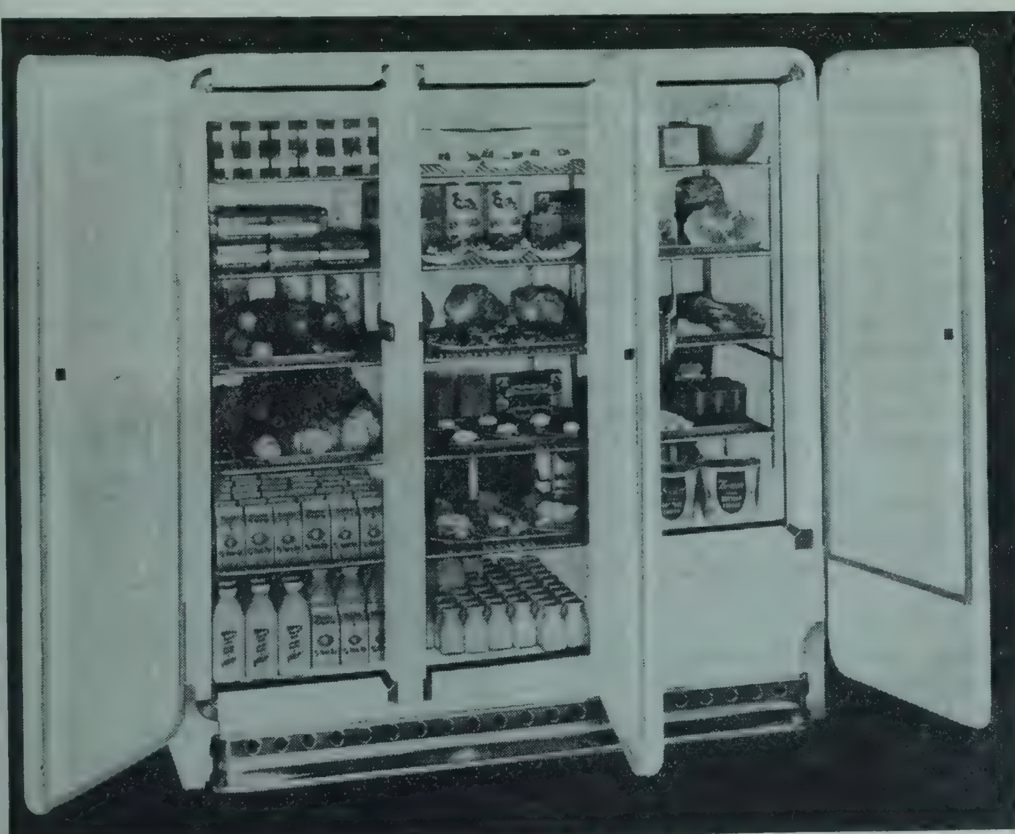


Fig. 9. Reach-In Refrigerator.

perform specific functions of merchandising, dispensing or storage, according to the need for which purchased.

When intended for sale to a grocer or other food merchant, the reach-in is usually supplied with glazed display service doors. (See Fig. 8a.) If for use in an eating establishment, the doors are usually solid; always so when the cabinet is exposed to the direct radiated heat from cooking equipment. An ice cube freezing unit may be part of the interior equipment. If intended for meat storage, the box may be equipped with meat rails and hooks in one compartment, with a full-length door; shelves and racks in the remaining compartments to accommodate butter, eggs, milk or other perishables. Small food stores may depend entirely on a reach-in for their refrigerated storage. In larger stores it often supplements the display case.

Reach-ins are made in a wide range of sizes, capacities starting from 16 cu ft and going to 100 cu ft or more. They are available for unit or remote condensing unit installation.

Wood and steel are used in various combinations. Exteriors are finished in porcelain-on-steel or synthetic enamel; interiors of enameled sheet steel or porcelain. Wall thickness, where wood exterior and interior are used, averages 4 in., with 2 in. of insulation, although some cabinets have 5-in. walls with 3 in. of insulation. Some boxes are also supplied with exterior and interior of stainless steel, with framework of either steel or wood, and have proved popular with eating establishments and institutions. The trend is to an all-steel cabinet.

Typical specifications. Following is a typical specification covering a 40 cu ft reach-in refrigerator, for use in a retail food market:

Dimensions (overall): Width 52 in.; depth 33 in., height 72 in.
Doors: Two $20\frac{1}{2} \times 23\frac{7}{8}$-in. service doors; one full length door to meat compartment, $20\frac{1}{2} \times 59$ in.
Insulation: 3 in. in doors and walls.
Capacity: Shelf area 30.9 sq in, including floor; net capacity 40.4 cu ft.
Equipment: Adjustable bar type, tinned shelves. Galvanized bar iron meat racks Tinned removable hooks. Automati light switch.
Finish: White porcelain exterior front anc ends; white porcelain interior.
Refrigeration Equipment: For 100 F, am bient, heavy service and 40 F interio temp, $\frac{1}{4}$-hp air-cooled condensing unit one finned coil, overhead, 36 in. long $\times$ 1 in. wide $\times$ 7 in. high; eight $\frac{3}{4}$-in. tubes $\frac{1}{2}$-in. fin spacing; one thermostatic ex pansion valve.

Miscellaneous Applications

In addition to the three basic types o commercial refrigerator described, ther is a variety of special applications, whicl will be briefly enumerated as follows:

Back-bar refrigerator. Designed for us with a soda fountain, for storing perishabl foods and chilling beverages in connectio therewith. A typical size is 20 in. deep b 36 in. high; length corresponding to th length of the fountain.

Beverage cooler. Chests or cabinets in tended for storing bottled beer and sof drinks, produced in a great variety o styles and designs. Usually self-contained In the "wet" type, the contents are im mersed in a refrigerated water-bath. In th "dry" style of design the cold well prin ciple is utilized. The latter may emplo forced air circulation.

Candy.* Refrigerated candy display case appeared in commercial volume during th

* Prepared for this chapter by A. W. Bireley, Gener Electric Company.

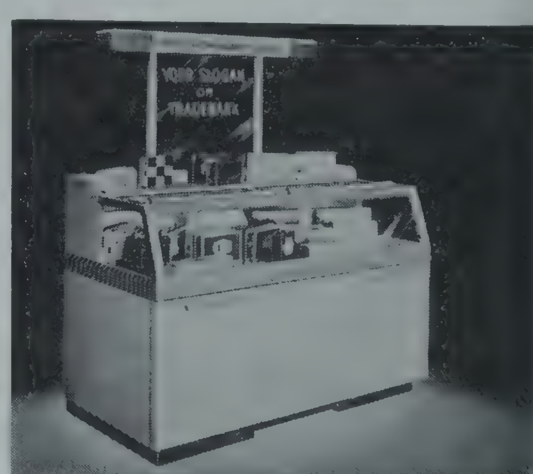


Fig. 10. Refrigerated Candy Display Case.

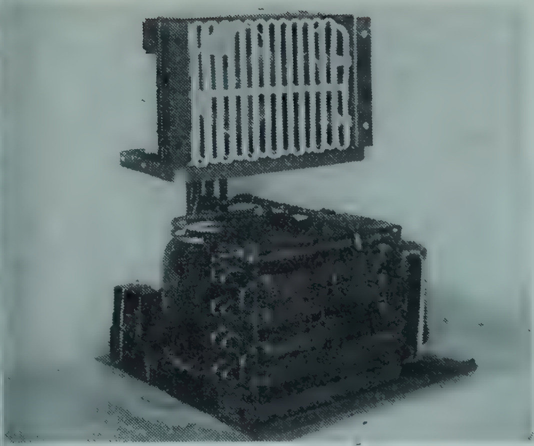


Fig. 11. Candy Merchandiser Refrigeration Machine.

post-war period 1946–1950. This resulted from pre-war development investigations which demonstrated the merchandising value of these devices by candy sales increases following the installation of refrigerated candy display cases in retail establishments.

The majority of these cases serve a triple purpose. (1) They maintain refrigerated display and storage conditions for the candy. (2) They provide merchandising centers for candy in retail establishments. (3) They provide advertising display space for the candy manufacturer distributing the cases.

Desirable conditions for retail storage of chocolate candy are 68 to 70 F dry bulb temperature with relative humidity less than 60%. Under these conditions, the attractive chocolate coatings of fine candies can be maintained with little or no change for long periods of time, and changes caused by condensation on candy removed from a refrigerated display case into warm humid room conditions are minimized.

Typical candy merchandisers arranged for self-service are shown in Fig. 10 and Fig. 11. A forced air refrigerating machine designed for this application is shown in Fig. 12.

Dough retarder. An adaptation of the reach-in refrigerator, used by retail bakers for storing raw doughs and mixes to retard natural fermentation, requiring high humidity to prevent crusting. Some types are offered with built-in coils for chilled water. These devices are equipped with racks to take standard size bun pans. (See Fig. 5, Chap. 37.)

Ice cream cabinet. Chests or cabinets designed for the storage and dispensing of ice cream, ices, etc., usually in bulk. Produced in sizes designated by the number of "holes'- or compartments; "single-row," "double' row," as in **Fig. 12.** With variations and refinements this device is also used for storing and dispensing frozen foods, factory-packaged ice cream or as a "home freezer." Refrigeration characteristics are similar to those of any low-temperature chest or cabinet. Temperature should be adjustable through a range of +10 F to −10 F, while operating in a 110 F room.

Florists' refrigerator. Standard models are designed to offer refrigerated storage in combination with the display feature, often constructed as a walk-in cooler, with decorative exterior and special interior shelf arrangement according to the customer's preference. The reach-in type refrigerator, with a decorative exterior and interior, special shelving, interior illumination, etc.,

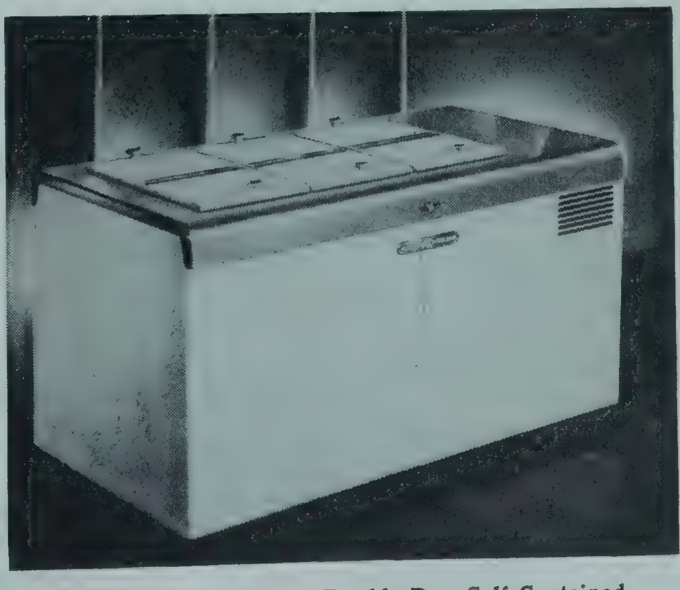


Fig. 12. Typical 6-Hole Double-Row Self-Contained Ice Cream Cabinet.

is also successfully employed for this purpose. Self-service display cases for the sale of packaged cut flowers is a recent innovation.

Mortuary Refrigerators.* One of the important commercial applications, considerable incentive to which was given by the services during the last World War, is the refrigeration of morgue spaces or what are generally known as mortuary refrigerators. The refrigeration requirements for this application are figured in the same manner as are ordinary commercial refrigerators. Construction is modified to suit the requirements of the application. The principal users of this type of refrigerated space are municipal morgues, hospitals, medical schools, and undertaking establishments.

Individual carriage and tray type of storage is used generally except in some medical schools. The unit of storage consists of the space necessary to accommodate a tray resting on a telescopic slide. Each of these is usually behind an individual door that has an opening of approximagely 26″ width, 24″ height and a depth of compartment of 7′. Doors are arranged two or three high.

A representative style of mortuary refrigerator with exterior dimensions approximately 39″ wide, 96″ deep, 75″ high has been developed with two of these doors, one over the other, and a ventilated unit compartment in a depressed section at the top front of the refrigerator. This two-body unit is insulated with 4″ of sealed fibreglas or cork between metal exterior and interior wall covering and lining. A $\frac{1}{3}$ hp air cooled unit and a blower coil of balanced capacity are provided forming a self-contained two-body unit. Two or three of these are used to provide four or six body capacity. Where larger capacities are desired or where the structure of the building indicates the built-in type, the walls, floor and ceiling of an alcove, approximately 8′ deep and 8′ high (for 2-body in height) (or 9′ high for 3 bodies in height) are insulated with 4″ of corkboard or equivalent applied in the usual manner indicated elsewhere in the manual under cold storage insulation finished on the inside with cement plaster or tile. A 6′ wide alcove therefore provides space for four or six bodies and two or three bodies additional can be added to the capacity for each 3′ increase in the width of the alcove. The 6 or 9 or 12 door front is usually made up complete including panel above the doors in front of the coil and bolted to the bucks at the front of the insulation on the walls.

The temperature maintained is 34–38 F. The usual calculations of wall heat leakage to obtain this temperature with the type and thickness of insulation used in the expected average temperature in the space where the refrigerator is located are to be taken from the instructions covering cold storage spaces elsewhere in the manual. This constitutes the major refrigeration requirement so that satisfactory results may be obtained with the use of refrigerating equipment that meets these requirements with very little overage for "service factors" or "product load." However, as these spaces are seldom inspected it is essential that equipment be provided where coils are of ample size to eliminate the possibility of freeze-up of the coil and compressors be provided with motors operating under less than normal loading.

The exception to the above-temperature requirements and arrangements applies to medical schools, where the cadavers are suspended from overhead tracks (similar to quarter rails in a meat refrigerator). Special hangers have been developed for this purpose. The temperature of this space is usually maintained at 34–38 F but some medical schools desire 26–30 F and the usual adjustment in refrigeration capacity of the units and the type of coil selected would apply. Occasionally, the medical school desires to make frozen cross sections of specimens which requires an additional small compartment maintained at approximately 0 F.

Construction

In the design and construction of commercial refrigerators, the purpose and characteristics of the fixture may impose a refrigeration problem not encountered in a simple insulated enclosure. If the fixture i

* Prepared for this chapter by Fred B. Green, J. P. Pfeiffer & Son, Baltimore, Md.

partially enclosed in glass, has glazed doors, or is not completely enclosed, the problem is thereby heightened. Following are the more important considerations that must be taken into account:

Insulation. The outside heat which passes through the insulation of a display case, reach-in, walk-in cooler or other commercial refrigerator, is intensified by the service load, to a degree that must be fully compensated in the design of the refrigerator and the insulation and other materials used. Elements of the service load include the frequent opening of doors, exposure of the fixture to radiant heat from such heat-producing agencies as cooking equipment or ovens, illumination, body heat, physical properties of the product to be refrigerated, and the cooling load of warm products placed therein.

The leakage of heat through glazed panels and doors must also be considered. This does not depend upon the thickness of the glass, but upon the air spaces sealed between the multiple thicknesses and their position in relation to one another. In normal service, tests have shown that the heat load factor for glass in a display case employing a single thickness is nearly five times that of a four-thickness panel; three times that of a three-thickness panel and about 1.8 times a double thickness panel.

In open type self-service refrigerators, where the display compartment is exposed, the problem of insuring proper refrigeration is rendered vastly more complex. Refrigeration requirements of such equipment have already been discussed.

In selecting insulation material, preference is usually given to a type that is least subject to moisture and passage of moisture vapor, and which at the same time adds structural strength. Corkboard was for many years the most widely used material. However, in recent years other materials have been successfully utilized. In using wood fibre, glass or mineral wool insulations, care must be exercised to prevent packing or sifting and to reduce infiltration of moisture vapor to a minimum. Physical characteristics of other types must likewise be taken into consideration if proper results are to be secured. All manufacturers strive to design a fixture that may be operated as economically as possible by the customer.

Evaporators. In factory-built fixtures, the type, size and arrangement of coils is generally worked out on the basis of experience, together with tests for the particular function to be performed by the fixture. However, where the equipment will be subjected to unusual conditions imposed by climate, nature of product and service, standard practice is altered according to the pre-installation data required from the sales outlet. Some manufacturers make a practice of refusing to make shipment of any fixture until complete heat load data are submitted.

Condensing unit. The selection of a proper condensing unit may be determined in the same manner as for coils; i.e., on the basis of exact data covering the installation in question. Conditions peculiar to the particular installation must be recognized. For example, water-cooled units will not give proper service in localities where the water lines are placed near the ground surface, causing too high a temperature in summer, and freezing in winter. Water rates may be too high to permit an economical operating cost; supply may be uncertain; pressure may be variable. Location of the unit in the building is also a factor. In a cool basement, an air-cooled unit may prove suitable; in a heated kitchen, water cooling might be necessary. In some areas, the combination air-cooled and water cooled unit can be used to good advantage.

Temperature requirements. The temperature to be maintained in a commercial refrigerator obviously depends upon the commodity to be refrigerated and the type of installation on which the fixture is used.

Storage life of food is a function of storage temperature. As far as it is possible to generalize, the closer to the freezing point an unfrozen food can be held, without freezing, the longer is its storage life. There are some exceptions to this generalization. These exceptions and optimum temperatures for **long time** storage of various unfrozen commodities are given in tables of the chapters in Section II. These tables apply primarily to storage warehouses and

other applications **where the emphasis is on long-time storage for** one reason or another. For convenience of designation, these can be termed **wholesale storage** temperatures.

For frozen foods, the lower the temperature at which they can be stored, the longer they will keep. Good food technology and practical considerations have established zero degrees F as standard practice. Most frozen foods will retain excellent quality for six months to one year if held at zero degrees F. See chapters in Section I.

There are many applications of refrigeration for the storage of unfrozen foods where temperatures higher than **wholesale storage** temperatures are commonly and satisfactorily used. The household refrigerator is an example. Here, temperatures as high as 50 F or above with ice as a refrigerant were common before the advent of the mechanical refrigerator. Modern mechanical household refrigerators carry storage temperatures of 40 to 45 F with consequent longer storage life for the foods stored.

In certain types of commercial establishments (grocery stores, restaurants, etc.) **food is brought in to be sold and turned over as quickly as possible.** Experience shows it is rarely on hand for more than 24 to 72 hours. For the sake of convenience, the temperatures used in such applications can be designated **retail storage** temperatures. Commercial fixtures described in this chapter are mainly used for this type of work.

In this service, as in the household refrigerator, two or more varieties of foods are nearly always stored in one fixture. This mixture of foods, the short storage time, and other operating considerations make the use of **wholesale storage** temperatures unnecessary or impractical. Fixture temperatures of 35 F or above have long been established as practical, satisfactory and economical for **retail storage** applications. Higher temperatures than 35 F are often necessary due to limitations of the equipment itself, particularly some display fixtures (See Tables 1 and 2). At 35 F and above, automatic defrosting of cooling units is obtainable by use of the simple low pressure control usually supplied as part of the refrigerating condensing unit. Thi[s] eliminates operating supervision and othe[r] problems, and assures better performanc[e] of the system. Problems thus eliminated o[r] reduced to a minimum are—necessity fo[r] manual defrosting, increased cost of addi[-]tional equipment required to provide posi[-]tive defrosting, food spoilage due to ele[-]vated temperatures when coils collect ex[-]cessive frost, occasional freezing of foods and frequent control adjustments due t[o] weather changes. These problems are par[-]ticularly acute when attempts are made t[o] operate the open-type display cases at tem[-]peratures below 35 F. In all types of fixtur[es] refrigerated by circulation of air ove[r] cooling units, it is essential that this cir[-]culation is not interfered with if fixtur[e] temperatures are to be maintained an[d] automatic defrosting of the cooling unit be obtained.

On some installations where **retail stor[-]age** temperatures are used in most fixtures due to the infrequent delivery of bulk sup[-]plies of perishables, or for other reasons some storage facilities are required on [a] **wholesale storage** basis. Such application[s] are the exception rather than the rule. Such installations are usually large enoug[h] to justify separate storage space for vari[-]ous commodities. The refrigerated space i[s]

Table 2. Recommended Retail Storage Temperatures, °F

(For use under normal or average operatin[g] conditions)

Type of Fixture	Average Temperature Range*	
	Minimum	Maximum
Walk-in cooler	35	42
Reach-in refrigerator	36	45
Restaurant service refrigerator	36	40
Single duty meat display case	35	42
Double duty meat display case	36	42
Vegetable case, closed	38	48
Vegetable case, open	40	55
Grocer's dairy refrigerator	36	42
Baker's dough retarder	35	40
Florist's display refrigerator	40	50
Florist's storage cooler	38	45
Frozen food cabinet	−5	0

* Average of readings in several parts of fixture

usually a walk-in cooler. When temperatures below 35 F are required for such applications, the equipment should be engineered to fit the need including positive defrosting methods, the necessary controls should be included and the proper operating supervision must be given to assure performance. Temperature alone is usually not the sole factor, as moisture conditions and air circulation are often fully as important. General rules for specific commodities include:

Meats. If chilled when delivered to the user, store in a walk-in cooler, at a minimum temperature of 35 F. Moisture conditions must be confined to a relatively narrow range, because if too high, bacterial growth, mold and sliming will be encouraged. If too low, excessive dehydration will occur. Air circulation must be positive at all times to prevent stagnation, but not so rapid as to cause drying out or "burning." Forced air blasts must not be permitted to strike products.

Fruits and vegetables. It is impractical to provide separate temperature zones to meet the widely varying requirements of different varieties of fruit and produce. The result is a considerably broader range of temperature than in the case of fresh meats. Here also moisture conditions are extremely important. A high moisture content will give the best results, as otherwise most kinds of fruit or produce will quickly wilt, shrink or dry out. On the other hand, some varieties of fruit and a few vegetables may be harmed by too much moisture so that the period of storage must be limited by the operator.

Frozen foods. In the case of display cases or storage fixtures of the closed type for frozen meats, fruits and vegetables or ice cream, recourse must be had to efficient engineering techniques for preventing too-wide temperature variations when doors or lids are opened. The even more exacting requirements of open-type self-service frozen food fixtures are discussed elsewhere in this chapter. Combination low- and normal-temperature fixtures present still other problems.

Bakery doughs and mixes. The principle of dough retarding is based on scientifically worked out formulas, in which the temperature of the stored mixture must be closely held to a predetermined level, usually between 34 and 40 F. The action of the yeast or other means of aerating and raising doughs is retarded or increased by small changes in temperature. Relative humidity should be high, 70 to 90 percent, in order to prevent crusting.

Flowers. If stored for long periods at near-freezing temperatures, cut flowers will suffer when exposed to room temperature. The tendency in designing storage fixtures is to provide a fairly broad range. In a display fixture, somewhat higher temperatures are practical.

Recommended temperatures. A consensus of reports from leading engineers shows that the minimum and maximum average temperatures of **Table 2** are recommended for the principal types of equipment.

If you searched this chapter for something which was not found in it, please let the editors know.

38. HOME AND FARM FREEZERS

THERE seems to be no record of who had the first farm and home freezer in operation as such. Some ice cream cabinets were used for the purpose, especially by sportsmen, before 1930. One manufacturer offered a frozen food cabinet suitable for this purpose during that year.[1,11] As the community locker storage plants grew in numbers, interest also began to develop in the individual type of freezer and storage because of the convenience it would afford the farm home. The first experiment station publication on such equipment appeared early in 1938 from Washington State College.[2] A limited number of other research agencies and manufacturers were then devoting time and effort to studying farm and home freezers and their application.[6,8,9,10]

Since 1938 there has been a rapid increase in the number of individually owned and operated farm and home freezers in the United States.

Convenience and better living are probably the home cabinet's most important contributions. It is near the point of production, and yet at the place where the food is consumed. Although the home cabinet is convenient, most owners have found it advantageous to use the services of the locker plant near them to perform the tasks which the owners of cabinets are not equipped to handle. This is true particularly of handling meat.

Because of the equipment, cleaning facilities, and sanitary conditions necessary, meat animals, particularly hogs and beef, are difficult to handle and prepare for freezing at home. Also, there usually are no chilling and aging facilities available. Most farm people either do not have the time or experience to undertake the preparation of meat for their freezers. In addition, small home freezers are so limited in freezing capacity that only small amounts can be frozen at one time.

The locker plant offers many additional services of which the farm and home freezer owners either need or wish to avail themselves. Some locker plants perform slaughtering services, but practically every plant gives services of chilling, cutting, and grinding meat; lard rendering; curing of ham and bacon; packaging and freezing; and they act as brokers for those wishing to purchase quantities of meats, in addition to renting lockers holding 200 to 250 lb of food. Whether all or part of the food is stored in the home freezer, these are valuable services at a low cost.

For those people living in suburban areas who do not raise their own meat animals the service of buying, cutting, packaging and freezing offered by locker plants at a nominal fee is not only a saving but a great convenience to the home-freezer user.

In the past, locker plants did not prepare and process vegetables and fruits for patrons, chiefly because the locker operations were not large enough to warrant costly labor-saving equipment, and the operations were too large and costly for hand labor. Since demand for this service is seasonal, the temporary labor required is often not available.

Locker plant-sized labor-saving equipment has been developed in recent years so that many plants now offer limited fruit and vegetable preparation services performed by the locker staff. Other plants

CLARENCE W. DUBOIS, Author Chapter 38. Born 10/16/09 in New Paltz, New York. Educated at Cornell University, BS, 1935. Formerly Fruit and Vegetable Inspector, NYS Dept. of Agric. and Markets, Rochester, N.Y., 1935; Extension Service, NYS College of Agriculture, Ithaca, N.Y., 1936–38; Investigator, Chemistry Div., NYS Experiment Station, 1938–43; Associate Professor, Head of Dept. of Food Preservation, Louisiana State Agric. Exp. Station, Baton Rouge, La., 1943–45; Consultant, D. K. Tressler and Associates, Westport, Conn., 1945–49.

Author of numerous contributions to trade and technical publications; Chapter 7 and 35 of 1946 Applications Volume, ASRE Data Books; Abstractor for Refrign. Abstracts. Member, Amer. Soc. of Refrig. Engrs.; Locker Committee, 1947 to date; Inst. of Food Technologists; Regional Section Committee, 1944–45.

At present, Food Technologist, Minute Maid Corp., Plymouth, Fla.

provide a well equipped kitchen where the locker patrons can prepare their own products. This kitchen has many small labor-saving devices as well as adequate utensils for such operations as blanching, and cooling vegetables, for quick and easy preparation.

A home or farm freezer is well suited to handle small loads such as vegetables and fruit. It is suited to farm slaughter of animals only where the carcasses are very small and handled in cool climates, where they may be chilled out of doors at certain times of the year, and the freezing load distributed over a period of several days.

There are many makes of farm and home freezers on the market. There are three general groups of cabinets, namely: (1) Reach-in or side-door group of cabinets consisting of three general types, (2) the chest or top-opening group of cabinets made up of three general types, and (3) walk-in fixtures consisting of two types. There are some modifications of the various types but this classification has been limited to the most prevalent types.

Classification of Farm and Home Freezers

1. Reach-in or side-door cabinets

Type A. Household refrigerator with a small section for storage of frozen products.

Type B. Half refrigerator and half frozen storage. One-half of the cabinet is devoted to a household refrigerator and the other half is for storage of frozen products. The two sections are separated by an insulated wall.

Type C. Completely adapted to freezing and storage of frozen foods only.

2. Chest or top-opening cabinets

Type A. A small chest cabinet for storage of frozen products.

Type B. A large cabinet consisting of two or more compartments—one for freezing, the other for storage of frozen foods after freezing.

Type C. A chest which has in combination a refrigerator and compartments for storage of frozen foods.

3. Walk-in fixtures

Type A. Combination walk-in cooler and walk-in or reach-in freezing and storage section for frozen food products.

Type B. A room exclusively for freezing and storage of frozen food products.

Reach-In Cabinets

The reach-in cabinet conserves floor space, making it particularly desirable for kitchen or pantry. This type has some advantage of accessibility if the shelves are not deep or too far apart. In the larger cabinets, the advantage of accessibility has been to some extent over-emphasized.

The Type A cabinet or household refrigerator is a dual-purpose refrigerator which has a large space at 40 to 50 F for cooling and storing foods and a small space, usually 1 or 2 cu ft, for storing frozen foods, at approximately 0 F (Fig. 1). Such a cabinet may be used as a supplemental freezer storage to a locker or a large farm cabinet. It also may be used in the urban home to store several days' sup

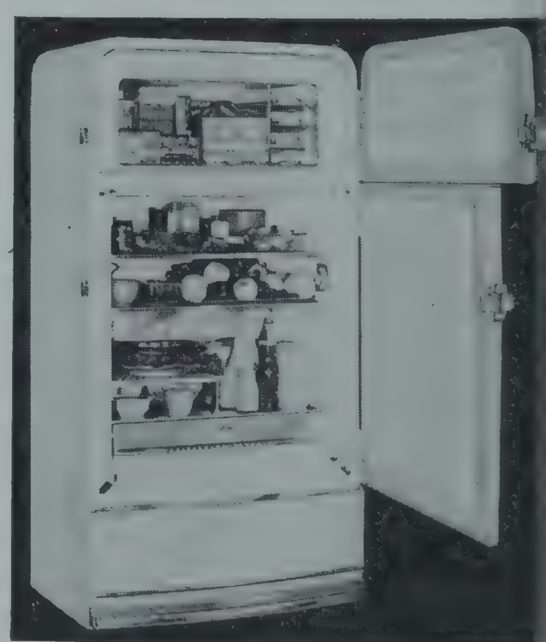


Fig. 1. Household Refrigerator with Storage Space for Frozen Foods. Type 1A.

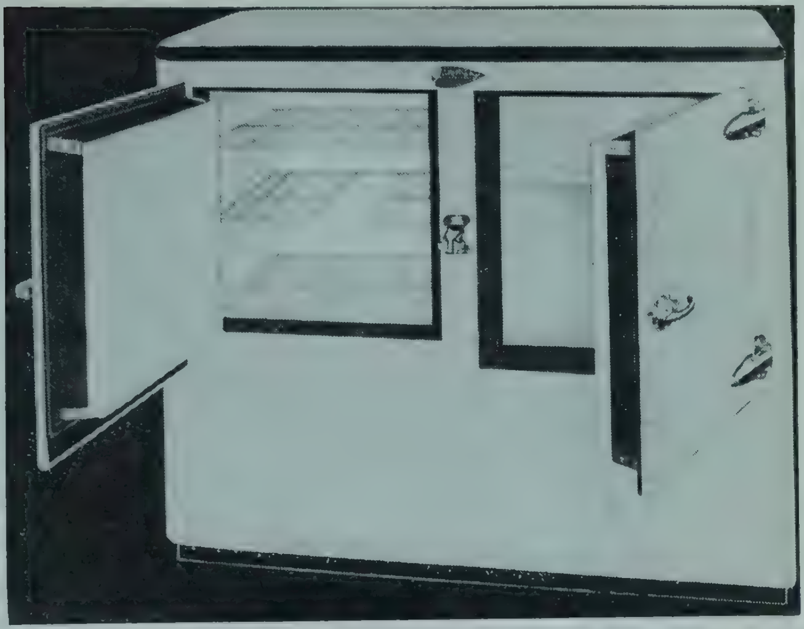


Fig. 2. Multitemperature Refrigerator with Household and Freezer Storage Space. Type 1B.

ply of commercially frozen foods purchased at stores. It appears that this type of cabinet with 1 or 2 cu ft of frozen food storage has a large potential market for urban homes. Close temperature control of both sections is imperative.

The Type B cabinet is half freezer and half household refrigerator, with about 5 cu ft in each section, as in **Fig. 2.** In general it is rather small for most farm applications.

The Type C or upright cabinet is exclusively a freezer and frozen food storage cabinet, as in **Fig. 3.** It is being made in small and large sizes. The smaller ones usually have one large door with smaller drawers or compartments so arranged to provide inner or sub-doors. Escaping air is replaced by warm moisture-laden air causing rapid frosting of the evaporator. The arrangement of inner sectional doors prevents the loss of much air from the freezer when opened. Some-times, accumulation of ice at door seals may cause the door to freeze and stick. Most new freezers are well designed with tight-fitting doors and good gasketing to prevent this.

Chest or Top-Opening Cabinets

Various types of cabinets in this group have many factors in their favor. They are relatively inexpensive because of simple construction and they operate economically. The chief objection is that people short of stature find it difficult to reach the lower parts of the cabinet.[4] The contents may easily become misplaced if the user is not orderly and systematic.

The Type A or small chest cabinet, of **Fig. 4,** has from 1.5 to 5 cu ft of space and is designed chiefly for storage, because of the limited space and refrigeration capac-

Fig. 3. Reach-In Cabinet for Frozen Foods Only. Type 1C.

ity. In some models, a limited amount of freezing can be accomplished. It is not particularly well adapted to farm application except as a small supplement to a locker. It is suitable for urban dwellers, relying mainly on commercially frozen foods, for space needed beyond that furnished by a domestic refrigerator.

The Type B or large chest type freezer and storage cabinet, of Fig. 5, has been designed for freezing in one section and 0F storage in another. Although this cabinet is designed to freeze foods, the amount that can be frozen at one time is limited by the size of the condensing unit and associated evaporators.

Type C is a combination low-temperature cabinet and household refrigerator.

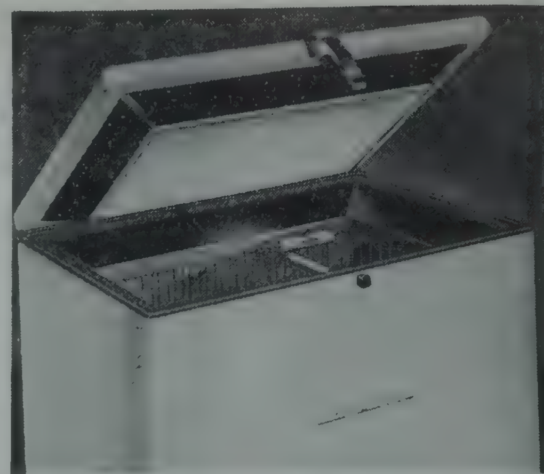


Fig. 4. Small Chest Type Storage Cabinet. Type 2A.

Walk-In Fixtures

The walk-in group has merit because of its capacity for roadside markets, large farms, plantations and ranches. The chief disadvantage is the initial cost. This type, however, may be economical where large quantities of food are handled or where the turnover of products is frequent enough to justify its use.

Type A, a combination cooler and frozen storage fixture, Fig. 6, has two rooms or sections, one of which is a walk-in cooler

Fig. 5. Two-Compartment Home Freezer—One for Contact Freezing; Other for Storage. Type 2B.

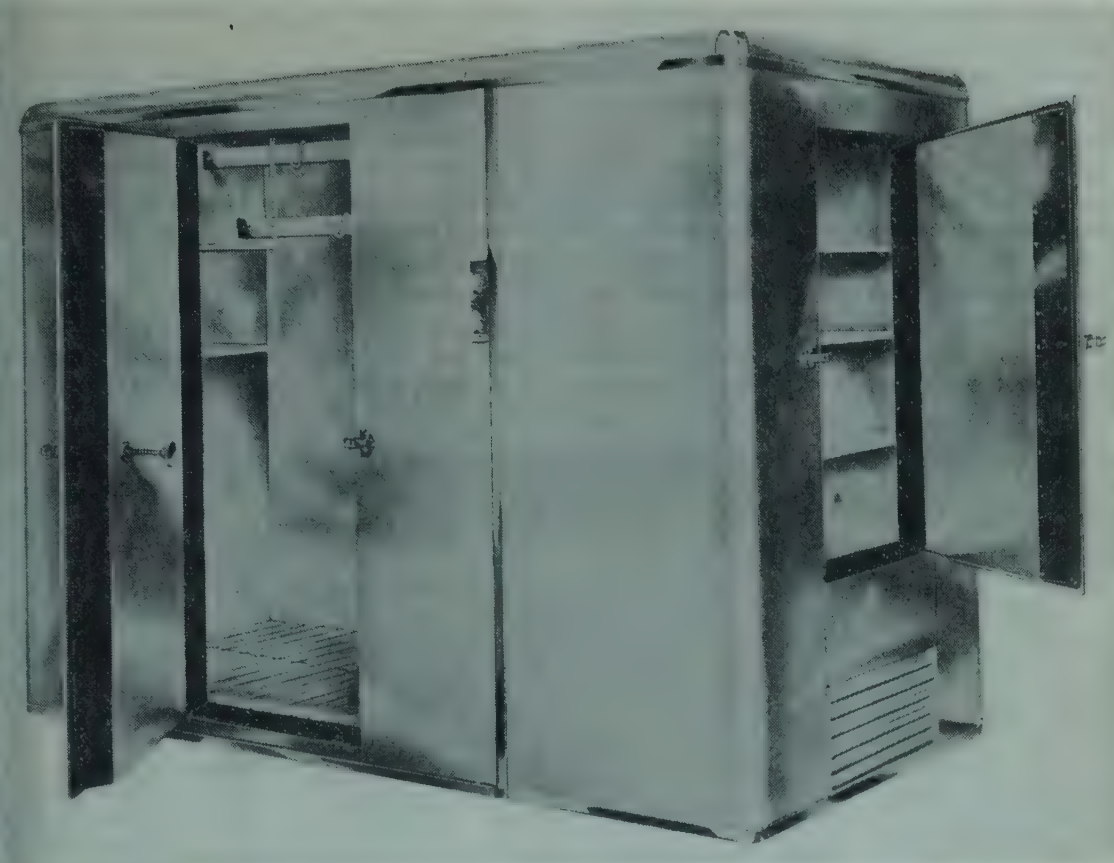


Fig. 6. Combination Walk-In Cooler with Reach-In Freezer and Frozen Food Storage. Type 3A.

or chill room at approximately 35 F and the other section either walk-in, reach-in, or chest type at 0 F with freezing facilities incorporated. The 0 F section could be entered through the chill room. Such a fixture has much in its favor where large quantities of food are handled. In areas and climates where refrigeration previous to freezing is necessary to chill and keep products cool, such as meat, and if there is no locker plant nearby offering such services, this type is of particular value.

Type B, a frozen storage room only, Fig. 7, has a 0 F room without cooler storage or chilling facilities. It is less practical for most applications than the combination with cooler and frozen storage. Like type A, it usually includes freezing facilities.

Application Problems

In some combination units, the coolers have been dependent on refrigeration by heat leakage from the cooler or household section to the 0 F compartment. Some have given trouble because of variations in surrounding temperature, affecting the heat leakage rate. Unless cabinets of this type are kept where the temperature is reasonably high and uniform at all times of the year, they are impractical. When the ambient drops below 50 F, the food in the high-temperature section is apt to freeze.[5]

Many freezer users demand more from their freezers than they should expect. Most small freezers can freeze but a few (not more than 10) pounds of food per day without interferring with the storage temperature and causing the machine to run continuously. The freezer will give satisfaction if the food is properly prepared and packaged and if the compressor is not overloaded trying to freeze too much warm food at one time.

The **building** of home and farm freezers

by farmers and home owners is generally a questionable practice.[3,4] Special tools and a certain amount of special knowledge is required. If the insulation is not thoroughly sealed against moisture infiltration and if the proper size evaporator and condensing unit are not installed properly, trouble is soon experienced. Furthermore, there usually is no financial saving over buying a commercially manufactured cabinet within reach of local service.

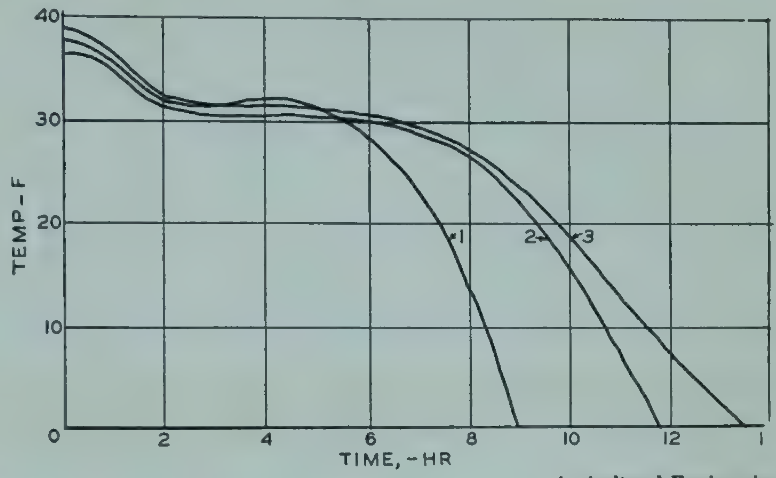
The size and type of cabinet required for a given family is not definite. There are many factors which affect the individual requirements, such as number in family, section of country, length of growing season, habits of eating and preserving, selling price of cabinet, amount of food processed at home, whether or not locker plant facilities are available and extent to which these facilities are used. All must be considered. There is some question as to how extensively urban and suburban families will process their own foods. It seems probable that most urban and many suburban housewives will purchase commercially frozen foods, instead of buying fresh produc and processing and freezing their own. A regular household refrigerator with 1 cu f or more of frozen food storage space migh be adequate for such a supply of foods.

It seems that there will be a demand fo cabinets of 1.5 to 5 cu ft for use as supple mental storage to a locker plant, for sub urban families and those in villages wh have small gardens, or for city dweller who use commercial frozen foods. Sports men may also have need for such cabinets

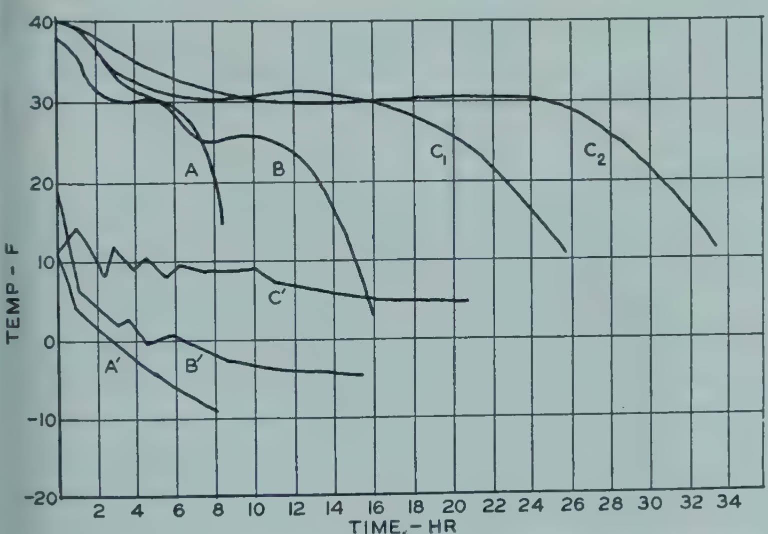
A large cabinet seems necessary for farm families which produce and preserve mos of their own yearly food supply of meat poultry, fruits and vegetables by freezing Based on past research and surveys,[3] cabinet ranging from 18 cu ft (holdin approximately 700 lb) to 35 cu ft in ca pacity (holding approximately 1250 lb would be required. In general, 30 to 40 l of packaged food can be stored in 1 cu f of space. Surveys indicate a cabinet wit 24 cu ft of space to be adequate for farm where there are five people in the family

Fig. 7. Walk-I Freezer and Fro zen Food Storage Type B.

Fig. 8. Freezing Rates in Typical Home Freezers.



(a) Differences in freezing rates of three samples, each weighing 3½ lb and of from 3¼ to 3½ in thick. Cabinet 1 with two compartments with coils built in the wall was powered by a ½-hp unit. There was a fan mounted in the back of the freezing compartment in a duct opening at the bottom and the fan opening at the top. The air was drawn through the duct and was forced out at the bottom. Cabinet 2 had a freezing compartment around which was a metal jacket. The jacket, refrigerated by coils, contained eutectic brine. The roasts were placed in the cylinder against the brine wall. Cabinet 3 was much like Cabinet 1 in design except plate evaporators were used. The roasts were placed on shelves and frozen by air circulation. The greater length of time required to freeze the samples in Cabinet 3 was thought to be a result of a smaller fan in the compartment, moving less air over the products.



(b) Temperature drop curves taken in the center of roasts showing difference due to freezing conditions with sizable loads. Curve A shows the temperature drop in a roast frozen in a locker plant freezer on horizontal plates. The total freezer load was 120 lb. The system possessed adequate capacity. Curve A′ shows the temperature of the air over the load being frozen. Curve B shows the temperature drop in beef roasts placed on a horizontal plate in a one-compartment farm cabinet, operated by a ½-hp air-cooled compressor accompanied by a 70-lb load of beef. Curve B′ shows air temperature over samples represented by the B curve. Curve C_1 shows the temperature drop in roasts of beef placed against a vertical plate evaporator in another farm cabinet powered by a ½-hp compressor. The load totaled 90 lb of meat. Curve C_2 shows the temperature drop of a roast frozen in the same cabinet but with no air circulation, and not in contact with the evaporator. Curve C′ illustrates the air temperature in the cabinet around samples being frozen, shown by Curves C_1 and C_2.

Cabinet Designs

There are many factors to consider in cabinet designs. Most of the freezing and storage cabinets constructed in the past have had two sections, one for freezing foods and the other section of one or more compartments for storage. Some of these large cabinets used fans mounted in the freezing section to speed the freezing process. Air circulation over family-size packages decreases freezing time by about 50 percent, compared to freezing in still air.[3,6,7,11] (See **Fig. 8.**)

Fig. 9 shows a typical cabinet designed for **contact freezing.** In the smaller cabinets where the evaporator and compressor are small, the addition of a fan is of little value, first, because of the amount of heat given off by the fan motor and, second, due to the increased heat leakage caused by the air movement. Shelves have been found to be advantageous in freezing compartments for spreading out packages where air blasts are used. Shelves, and some types of baskets have been considered a nuisance in the storage compartment of chest-type cabinets. They are wasteful of space and may be hard for the housewife to handle. Finned coils and/or exposed tubing frost up rapidly and require positive means for defrosting. Plates or coils built into walls are desirable in leaving a flat unobstructed interior surface, from which loose frost can easily be scraped (Figs. 9 and 10). These smooth surfaces are also advantageous for contact freezing. Warning devices that will notify the owner when the temperature in his cabinet has risen to an undesirable height have been optional with some makes. A built-in thermometer is a convenient accessory.

Experience indicates that freezer cabinets should not have an exposed, easily adjusted thermostat. Although the control thermostat should be adjustable by servicemen, it should not be open to manipulation by the user. Uniform, well-controlled temperatures are important for preserving quality in stored frozen food over prolonged periods.[5,6]

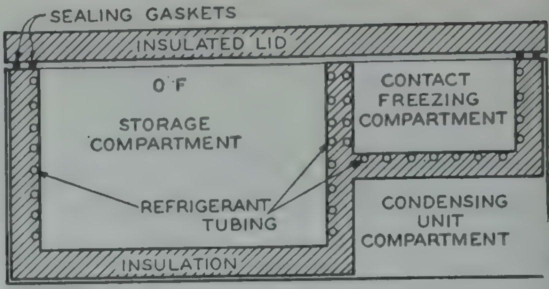


Fig. 9. Cross-Section of Cabinet with Contact Freezer.

Some of the present chest cabinets have a temperature differential of 5 F or more between the top and the bottom of the cabinet. Some difference is inevitable, but this is of little concern, as long as the temperature is 0 F or below in the space where food is stored if held for a normal period which is usually eight months to one year.

In cabinets which are equipped to freeze foods, some provisions for **ice-making** to provide ice for chilling vegetables after blanching would facilitate better handling of foods during warm weather and in warm climates. This applies chiefly to vegetables and fruits. Precooling by iced

Fig. 10. Removing Frost from Side Wall of Cabinet.

water will aid in handling larger loads and reduce possible spoilage hazards.[6]

Information should be made available by the manufacturer to the prospective buyer of a farm and home freezer so that the buyer may select the most practical equipment for his individual application. The buyer needs to know:

1. The total food-storage capacity of a cabinet in pounds. (NEMA has established a standard of 35 lb per cu ft.)
2. The weight of food that may be frozen in a 10-hr period in the freezing section while the unit maintains a uniform temperature of 0 F in the storage section.
3. Whether or not the cabinet will pass through the standard 30-in. door.
4. The availability and reliability of repair service.
5. Quietness of the refrigeration machinery.
6. Type of evaporator.
7. Method of defrosting.
8. The insulation material, thickness, and how well sealed against moisture infiltration.
9. Simplicity of mechanism to assure freedom from mechanical difficulties.

Mechanical and Electrical Interruptions

The user is particularly interested in the consequences of an equipment or power failure. Generally power failures are not sufficient to cause any great concern. Usually these failures are of less than 5 hr duration unless caused by floods, heavy wind, rain or snowstorms. In such cases there may be some cause for alarm.

Mechanical troubles usually can be repaired within a few hours before the frozen foods have thawed, provided the breakdown has been discovered when the failure occurs. Some manufacturers have well organized dealer service organizations to handle the repairs and services on such vital equipment. This seems necessary for continued success and satisfaction in farm and home freezers.

The length of time that is required for frozen foods to warm up during a failure in equipment or power depends on several factors. They are principally: (1) Cabinet size, (2) the amount and kinds of foods in the cabinet, (3) the temperature at which the foods are stored in the cabinet, (4) the ambient temperature of the cabinet and (5) the insulation thickness. Tressler reported[11] on a well-filled General Electric cabinet of 2 cu ft capacity that 58 lb of ice did not begin to thaw until approximately 22 hr after the current was cut off. The ice at the top of the cabinet warmed up more rapidly than that at the bottom. Even the packages of ice at the top layer did not rise above 32 F until 96 hr after the compressor cut off (**Fig. 11**). It required 120 hr or 5 days for the packages of ice at the bottom of the cabinet to rise above 32 F. The cabinet and ice was at 0 F, and the room where the cabinet was located was at 80 F.

In work with a 5.1-cu ft Frigidaire cabinet, McCoy and Hayner[12] found that the food products starting at -6 F when the current was cut off warmed up to 20 F in 24 hr, or approximately 1 F per hr. At the end of four days the products at the very top were 34 F, while at the bottom they were 30 F. After five days had elapsed the products at the bottom were still 30 F, but those at the top had reached 38 F. The temperature of the room was 80 F (**Fig. 12**).

This information reveals that there is a rather fast warm-up of products from the storage temperature until the thawing point is reached, because of the low sensible heat value of products in the frozen state. At the thawing point, the warm-up is much slower, due to the high latent heat at this point. In general, the freezing or thawing point of most vegetables and meat is between 29 and 31 F. Fruits packed in syrup have a lower freezing point, ranging from 15 to 28 F depending on the concentration of the syrup and the kind of fruit. It is interesting to note that the syrup in which the fruit is packed has a freezing point lower than that of the fruit itself. The syrup may defrost but the fruit may remain frozen until 25 to 28 F is reached. In general most products are considered to have a latent heat value of approximately 100 Btu at the freezing point, demonstrating the reason for the slower warm-up from 25 to 31 F.

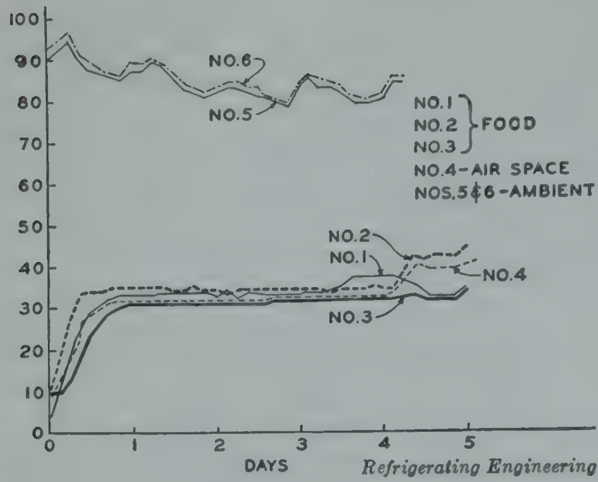
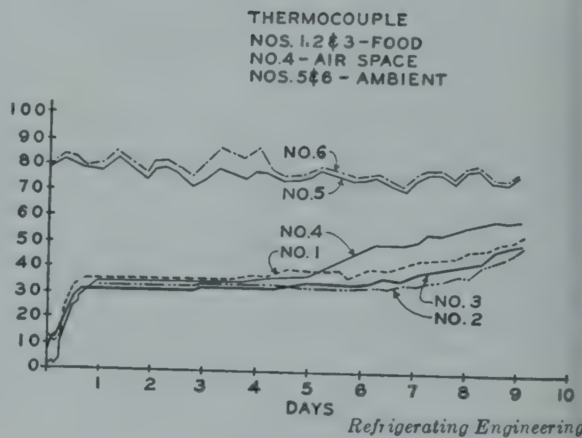


Fig. 11. (Left and below). Warm-up of 2-cu ft Home Freezer.



McCoy and Hayner also found that the above-mentioned cabinet when empty rose from 0 F at the top inside (below the top level of the evaporator) to 70 F in 16 hr. The empty cabinet was brought down from 74 F to 0° in 1 hr and 55 min.

DuBois and Tressler found that two other makes of cabinets having 24 cu ft of space when empty rose from 0 to 36 F in 18 hr.

The writer and others have found that there is some difference in the temperature (inside) between the bottom and the top. McCoy and Hayner also found this to be not more than 5 F if the top temperature were taken at the top level of the evaporator. The temperature if taken above this level is considerably higher than the rest of the cabinet. This illustrates that the storage section of the chest cabinet should have the evaporator extending as high as construction will permit, as foods stored above the level of the evaporator cannot be maintained at the proper temperatures. In the reach-in cabinet a portion of the evaporator must also be placed at the extreme top of the storage space, if the food in that location is to be maintained at the proper temperature.

In case there is a prolonged mechanical interruption, dry ice may be used to keep the food in the frozen condition.[11,13] There are variables of heat leakage and ambient temperature which make it difficult to recommend the exact amount

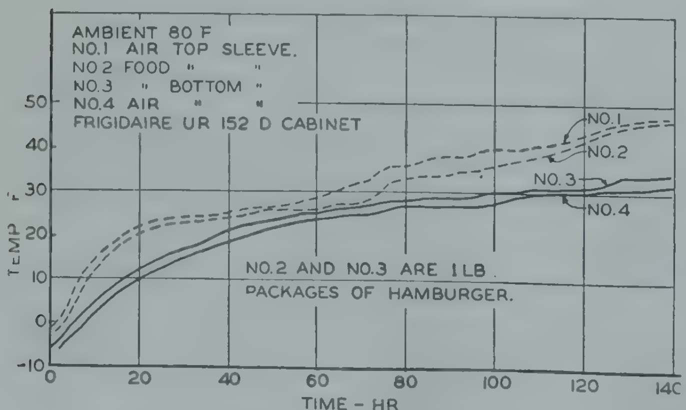


Fig. 12. Warm-up of 5-cu ft Home Freezer.

of dry ice to be used. Considering the ambient temperature above 75 F, the average cabinet from 5 to 20 cu ft in capacity, well and compactly filled, requires 5 lb of dry ice per 24 hr to keep the food frozen for each cubic foot of storage space occupied. The dry ice should be placed directly on top of the food packages with blocks placed at intervals. In partially filled cabinets a blanket of newspaper several sheets thick should be placed over the dry ice and food.

Defrosting the Freezer

Occasional defrosting of the farm and home freezer evaporator is necessary for efficient and proper operation of the equipment. How often, depends on many factors, the most important of which are type of cabinet, how well the foods are packaged and how often the cabinet is opened. Many times the surplus loose frost can be scraped off the evaporator with a blunt scraper, but there comes a time when a complete defrosting is necessary. The defrosting is done once or twice a year because the ice built up on the evaporator cannot be scraped away. When the surplus frost is removed by scraping, it is not necessary to remove most of the food. However, during a complete defrosting, all the food must be removed. The most desirable way is to select a cool day, but when temperature is at least 60 F and place the frozen foods in boxes or cardboard cartons. The containers are then stacked in a compact pile over which is spread insulating materials such as several thicknesses of newspaper or blankets. If piled and covered in this way, the food will remain hard frozen for 3 to 6 hr. The compressor motor then should be unplugged, followed by opening all doors. Provided the freezer is located where the temperature is 20 to 30 degrees above freezing, one may leave the freezer open until the ice has melted. This often requires many hours. One may place a sizable household fan in the cabinet to speed up the melting by the circulation of warmer air into the cabinet. If the owner has an electric heater, defrosting the cabinet would be greatly facilitated, by placing it in the cabinet to warm up the cabinet quickly. After the ice has been melted, the water removed and the cabinet wiped out, the motor should then be started. The food is then returned to the cabinet.

Conclusions

Research and experience indicate the following general observations regarding home and farm freezers:

1. Insulation should be a minimum of 4 in. of corkboard or equivalent.
2. Insulation should be sealed against moisture vapor infiltration.
3. The cabinet should be so dimensioned that it will pass through the standard 30-in. door.
4. Refrigeration system should be automatically controlled and be capable of maintaining 0 F or below in the storage compartment when cabinet is located in 110 F ambient, and should have capacity to do a stated amount of freezing.
5. Cabinets designed for freezing should have provisions for contact or blast freezing at 0 F or below.
6. Mechanism should be readily accessible for servicing operations.
7. No matter how good the cabinet or its mechanism, success and user satisfaction depend on application of the correct food technology for the foods prepared and stored.

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If you searched this chapter for something which was not found in it, please let the editors know.

39. DISPLAY OF FRESH FOODS

WHEN refrigeration was first applied to foods, attention was centered on its ability to preserve fresh foods in storage. Next scientific studies were made of refrigeration as it applied to distribution. Recently considerable work has been done on retaining the nutritive value of fresh foods by refrigeration, such as precooling the food and cars prior to shipment, shipping by body icing, and quick freezing at the source of supply. Serious consideration is now being given to refrigeration as it applies to the handling, merchandising, and display of fresh foods in the retail market. The subject of display of fresh foods must be divided into three classifications, each with its own problems:

1. Display of meats
2. Display of fruits and vegetables
3. Display of quick frozen foods.

Display of Meats

Use of refrigeration in the display of fresh meats at the point of sale is a recognized and accepted fact. Much time, effort, and money have been spent in the design of **refrigerated fixtures.** The fixture must be simple, permit full view of the product contained therein and have sufficient light to eliminate shadows throughout the entire case. The case itself must never be so elaborate as to detract from the merchandise on display.

The success of all meat display is freshness, for fresh meats have eye appeal. Keeping in mind that the refrigerated fixture is only an adjunct to the display of the merchandise, the display, using only fresh merchandise, should be built up to sell. This can be accomplished by making use of color contrast and ribbon display as in **Fig. 1.**

Different cuts of meats have color contrasts, which may be capitalized on in making up displays. A **ribbon display** will aid in showing off this color contrast and allow circulation through the fixture to permit air flow over the coil, thus getting full advantage of the refrigeration.

After the display has been built up around the three main points of freshness, color contrast, and ribbon form, it should be watched for dead spots. If for any reason any portion of the display does not attract customers, that portion should be broken up, changed or moved. Such spots waste valuable space and will eventually detract from the result as a whole.

The same type of procedure will apply to the display of fresh fish, as in **Fig. 2.** A fish display tank must be clean. A color contrast can be worked out very nicely; the pink color of shrimp contrasted against the flaky white fillets, and this against the reddish purple of fish steaks, or the red of fresh salmon. One may follow through with ribbon design so as to have a place for everything and everything in its proper place.

Eye appeal can be attained by following these points:

1. Cleanliness is of first importance to any successful food department.

LEE J. GIBBAS, Co-Author Chapter 39. Born 3/29/08, in Scranton, Pa. Educated at University of Cincinnati, ME, 1931. Formerly Maintenance Engineer, The Kroger Company, Louisville, Ky. 1932–35; Maintenance Engineer, Cleveland, Ohio, 1935–39; Refrigeration Engr., Cincinnati, Ohio, 1939 to date.

Co-Author Chapter 36, 1946 Applications Volume, ASRE Data Books.

Member, Engineering Society of Cincinnati; Amer. Soc. of Refrig. Engrs.; Program Chairman, Cincinnati Section, 1946–47; Chairman, Cincinnati Section, 1947–48; Cincinnati Nominating Committee, 1948–49; Section Director since 1949; Speaker at Cleveland and Cincinnati Section Meetings, 1946 and 1947.

At present, Refrigeration Engineer, The Kroger Company, Cincinnati, Ohio.

JOSEPH E. MERMAN, Co-Author Chapter 39. Born 6/12/09 in Bellevue, Kentucky. Formerly with Kroger Company, Cincinnati, Ohio, 1931–48; Asst. Refrign. Engineer, 1938–48; Manager, Commercial Refrign. Dept., Smith and Lohman, Inc., Cincinnati, Ohio, 1948–50; Instructor, New York Technical Institute, Cincinnati, Ohio, 1949–50.

Co-Author Chapter 36, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engineers; Secretary, Cincinnati Section, 1947–49; Section Program Chairman, 1948–49; Vice Chairman, 1949–50; Chairman, 1950–51; Speaker at Section Meetings.

At present, Cincinnati Branch Manager, R. H. Bishop Co., Champaign, Ill., and Sales Mgr., Mechanical Contractors, Inc., Cincinnati, Ohio.

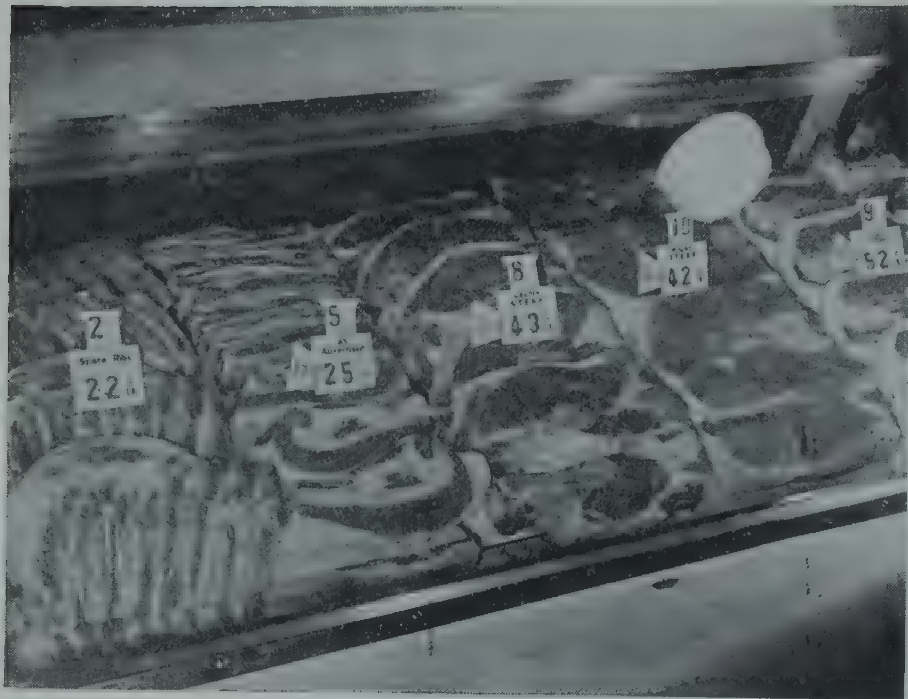

Fig. 1. Refrigerated Fixture Showing Ribbon Type Display of Fresh Meats.

Note valleys between different meat cuts which permit relatively free air motion from the refrigeration coil through the product.

2. Freshness is the foundation of all display.
3. Color contrast is definitely needed in eye appeal.
4. Ribbon type display permits color contrast and allows air circulation over the coil to get maximum refrigeration from the fixture.
5. Dead spots should be eliminated in order to take full advantage of the limited display space.

Display of Produce

It is a known fact that the produce dedepartment of any store can be the most profitable department, if properly handled. Location in the retail store is not important; a good job may be done in either front or rear. However, there may be an exception to this general rule where stores in much travelled and congested locations permit the merchandiser to take advantage of window display. A colorful window display will bring the shopper into the store. The larger and finer the display, the more will be sold.

Ribbon type display of produce, as in Fig. 3, together with proper color contrast, has a motivating effect in drawing the store traffic to this department. This treatment also permits freer circulation of air, carrying away the heat generated by most produce items. The use of mirrors behind a display will create an impression of massiveness.

Freshness is again the keynote to success. Rapid turnover goes hand in hand with freshness, because many items change in substance over a period of time. Proper ordering and speedy handling after the merchandise reaches the store is of great importance in maintaining freshness. Proper trimming and overnight storage in a refrigerated cooler are likewise essential.

Display of Frozen Foods

Prior to the war, the sale of frozen foods was becoming a vital factor in merchandising of fresh foods. However, wartime restrictions on mechanical refrigeration equipment cutting off the supply of zero degree temperature fixtures for the storage and sale of frozen foods forced this type of merchandise to assume a secondary place. Since the introduction of frozen foods in the retail field, they have been largely sold from the ice cream cabinet type of fixture wherein the product was hidden from view, often making it necessary for sales clerks

or shoppers to hunt for the desired commodity.

In the past two years, the manufacturers of frozen food display equipment, while still retaining the deep well type fixture, have worked toward eliminating the closed top and the need for poster type picture display in an "over the case canopy." By using the open-type deep well case with a mirror, the packages are readily reflected in the mirror, thus giving the shopper a good view of the commodities offered for sale.

There are now two types of open cases for merchandising frozen foods. First, the case with refrigerated dividing plates spaced to accommodate the frozen food packages and give plate contact to maintain the desired low temperatures needed for good preservation during display (see **Fig. 4**). Second, the well-type of case with the screen dividers which is cooled by gravity or forced air circulation in conjunction with hot gas or other means to positively defrost the coils and maintain proper temperatures (see **Fig. 5**).

Self-Service of Fresh Meats

Within the past year, the display of fresh meats in open refrigerated cases for customer self-service has made great strides. It has definitely arrived, and is here to stay. Self-service of fresh meats has eliminated another bottleneck in everyday shopping. Various sizes of roasts, steaks, chops or other popular cuts to meet every shoppers' needs are packaged and displayed under transparent wrapping materials. The shoppers have but to pick and choose, and be on their way. No longer is there need to wait in line for the head meat cutter to give personal service to everyone. However, the head meat cutter is still available behind a glass partition to offer personal service to those who may desire it. Product quality must be high and must be maintained if public acceptance of this method of merchandising is to continue.

To successfully merchandise fresh meats this way, they must be properly prepackaged under controlled atmospheric conditions. Opinions and practice as to temperatures to be maintained in packaging rooms vary from 35 F upward with no well established practice yet existing. The rate of bacterial growth increases sharply above 45 F, and at 70 F is quite rapid. Bacterial development and subsequent product deterioration in meat products can be kept at a minimum by proper temperature con-

Fig. 2. Display of Sea Foods Showing Both Ribbon Display and Color Contrast.

Reading from left to right, the *yellow* perch contrasted against the *white* fish and *silver* salmon, the *pink* shrimp again contrasted with the *red* fish steaks.

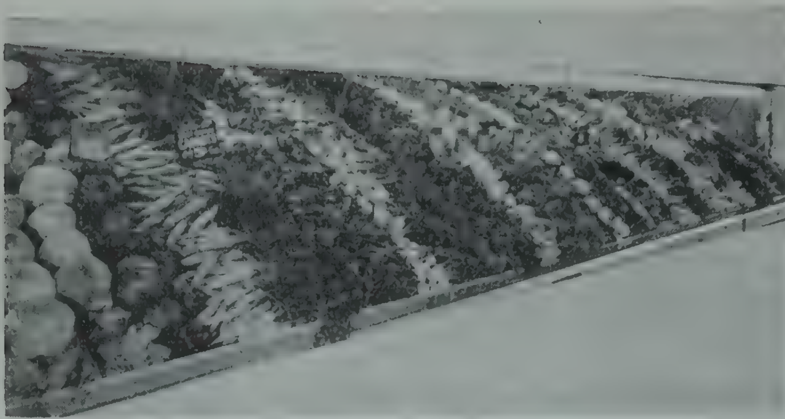

Fig. 3. Display of Fresh Vegetables Showing Ribbon Type and Color Contrast Together with the Illustration of Massiveness Created by the Mirrors in the Background.

Reading from left to right, *white* cabbage, *red* cabbage, the *orange* and *green* of carrots, *red* beets, *white* and *purple* of rutabagas, *dark green* broccoli and spinach, *white* parsnips, *light green* leaf lettuce, *red* ripe tomatoes, *creamy white* cauliflower, *yellow* wax beans, *purple-blue* egg plant, *green-white* celery, etc.

trol.[1] It would, therefore, appear that optimum temperature for cutting and packaging rooms would be 45 F or below. However, labor union objections have necessitated use of higher temperatures in some operations. A semi-dry atmosphere is also advisable so that whatever air is entrapped under the wrapper will have a minimum amount of moisture. This reduces condensation inside the package, thus permitting better display of the meats. It also reduces sliming, thus extending the life of the product.

The use of the proper packaging mate-

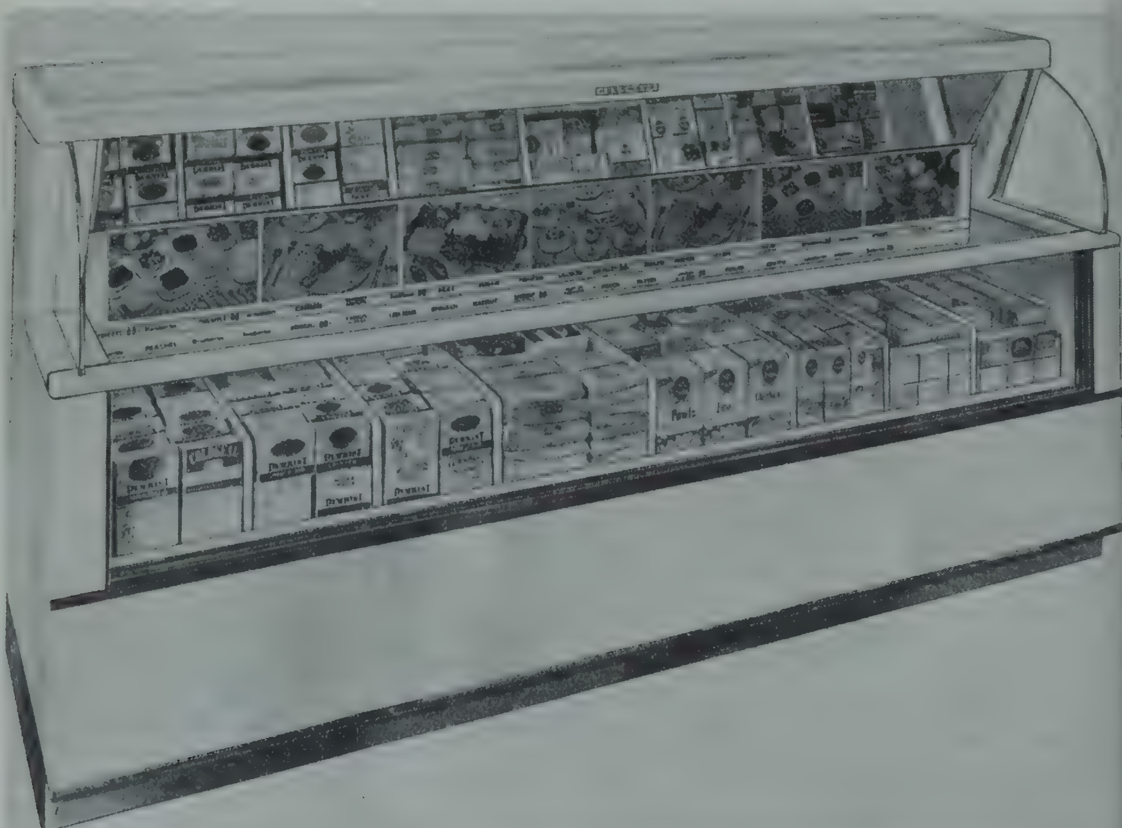

Fig. 4. Typical Open Type Frozen Food Display Case with Refrigerated Plates.

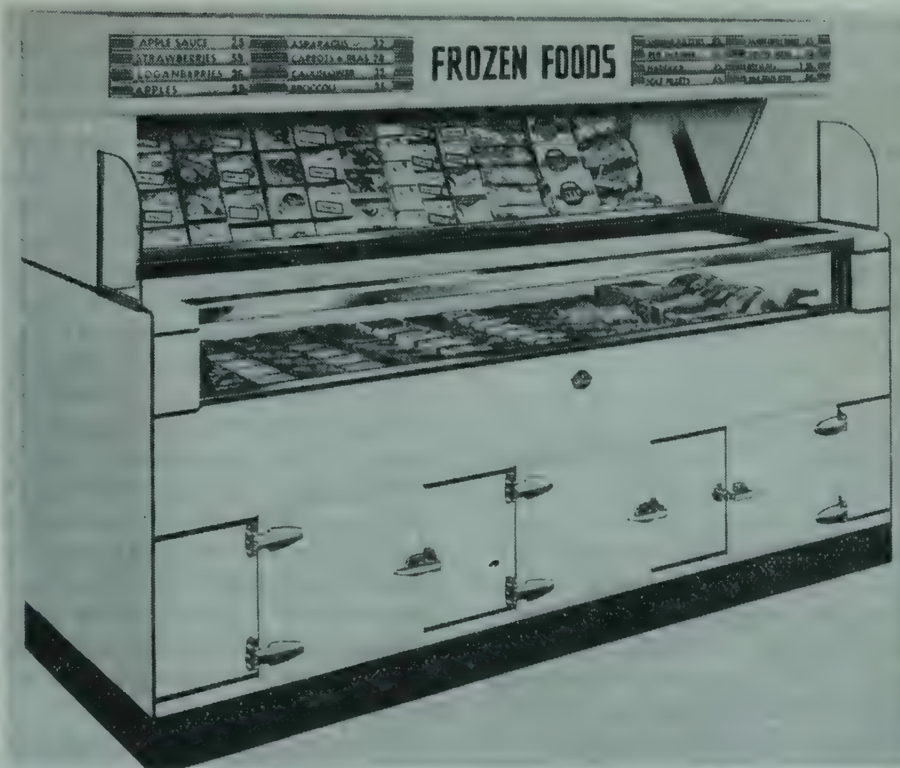

Fig. 5. Typical Open Type Frozen Food Display Case Cooled by Finned Coil with Hot Gas Defrost.

rials is also vital to success in this method of merchandising. None of the wrappers available today is ideal in all respects. New developments are taking place every day; consequently, only the general principles can be given here. For frozen foods, a packaging material which will pass the minimum of moisture vapor or oxygen is essential (see Chapter 11). For packaging fresh meats, some transmission of moisture vapor is desirable. Suitable grades of cellophane or pliofilm and possibly other materials are available.[2] Steaks and chops are best packaged when placed on a pasteboard or pulp tray then overwrapped with the proper grade of cellophane or other suitable material. For very large cuts such as roasts, an over-wrapped tray is suggested to provide rigidity and durability. Some sources recommend permitting the larger cuts of meat to drain under refrigeration for several hours before wrapping.[1] Bloody or greasy products should be labeled on the outside of the package, rather than having the label inside the package. Label should include name of cut, weight, price per pound and total price, yet keep the label as small as possible. The total price should be in bolder figures than the other data. Hamburger can be packaged in butter dishes or flat top trays with cellophane overwrapping. **Hamburger should be prepared daily in a refrigerated room, and only for each day's demand. It should not be carried overnight in the package.**

Sliced luncheon meats and fresh sausage require a different grade of wrapper than fresh meats.

Fresh whole poultry is more conveniently packaged in a bag or tube-like wrap than by using sheet wraps. This type of package is neater and withstands handling well. Pliofilm, cellophane and plastic films such as polyvinychloride or polyethylene[2] are available for this purpose. Cut up fresh poultry is best packaged in a transparent lined window carton or in a paper or wood dish overwrapped with film. If it is necessary to sell frozen poultry out of a fresh meat case, only one day's supply should be placed in the case and the balance kept in

freezer storage. Holding thawed frozen poultry for more than 24 hours reduces its quality and accelerates bacterial development and oxidative changes. Refreezing the poultry will not make it inedible, but it has a deteriorating effect on the quality of the product.

Before entering into the merchandising of prepackaged fresh meats, the seller should seek competent technical advice from some of the manufacturers of suitable packaging materials,[2] as success in this method of merchandising depends to such a large extent on suitable packaging.

Manufacturers of display equipment have developed fixtures which provide excellent display of prepackaged fresh meats for self-service. Good food technology indicates that temperatures near the freezing point of the product are optimum for this class of service. However, many practical problems involving case construction, operating of the refrigerating system and conditions surrounding this type of merchandising make these temperatures difficult, if not impractical to attain at the present state of this development.

The major refrigeration problem is to keep the cooling coils free from frost so they will function properly. In order to obtain near freezing temperatures, automatic defrosting of refrigeration coils by the simple low pressure control alone is impractical. This method of defrosting is limited to fixture temperatures of 35 F or above, with a reasonably high refrigerant temperature in the coils. In order to obtain the near freezing temperatures, methods such as time clocks, electric heater or hot gas defrost or other means of positively defrosting coils are a necessity, and these introduce operating problems and increase the initial cost of the equipment (see Chapter 37 for further details).

To sum up, the success of self-service merchandising of fresh meat is dependent on starting with a quality product, strict sanitary control, controlled atmospheric conditions in the packaging room, the proper type of moisture-vapor-proof packaging material, controlled temperatures in the display fixture, careful attention to the display of merchandise in the fixture, and rapid turn-over of the displayed product. If the quality of the merchandise presented is maintained, there is every reason to believe that the self-service display fixture will replace the service type, as shoppers are able to pick and choose the size and cost of the product to suit their particular need, without the delay of waiting for the meat cutter to give individual service. One unsolved drawback still remains to the self-service display of meats, namely discolorations due to light. Smoked meat products in particular fade or discolor very quickly when subjected to light. Fresh meats do not deteriorate as rapidly. It is hoped that in the future, methods of lighting can be developed to solve this problem, and speed the transition from the service display to the open-type self-service display.

Display Fixtures

The modern refrigerated service type meat fixture is the development of many years of intensive work on the part of the designers and manufacturers and is far removed from the old style back bunker used for a wrapping shelf. It is still a fresh meat holding fixture with limited space for display purposes. This case is now almost as antiquated as the old style ice bunker case. Modern merchandising demands self-service display.

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   Sylvania Cellophane—Sylvania Industrial Corporation, 122 E. 42nd St., New York, N. Y.
   Goodyear Pliofilm—The Goodyear Tire & Rubber Co., Akron 16, Ohio.
   Consult these manufacturers for proper materials and technique.

If you searched this chapter for something which was not found in it, please let the editors know.

40. REFRIGERATION IN RESTAURANTS

THE history of refrigeration began with man's attempt to provide a better means for keeping his foodstuffs from spoilage. Through all of these years of refrigeration improvements, the industry has been guided by the needs of two very large and important groups—the food servers and the food handlers.

The effective use of modern refrigeration methods preserves quality and prolongs useful life of perishable foods which play such an important part in customer satisfaction and food costs in the modern restaurant. Food deterioration continues as an important problem which will always exist wherever food is handled, unless means are taken to prevent the action of the enzymes and bacteria, molds and yeast which cause most of the trouble.

Refrigeration has proven to be the most effective preventative against this action simply because bacteria, molds and enzymes do not grow or multiply in cold temperatures and some are arrested or stopped altogether by below freezing temperatures. Perishable foods not refrigerated properly may become unsuitable for consumption, unattractive in appearance and unpalatable. Wilting, softening, loss of weight, loss of vitamin content, discoloration, molding, rotting and souring are some of the types of deterioration which can be retarded if perishable foods are kept under proper temperature conditions.

Dr. Gail Dack of the Food Research Institute, University of Chicago, comments on this subject as follows:

"Certain foods such as dairy products, custard and various types of meats support the rapid growth of some of the bacteria causing food poisoning. These bacteria are common in our environment, and no practical means has been found to keep them from contact with our food."

"One of the most common types is a certain **Staphylococcus,** which, if swallowed with food, is ordinarily harmless. However, if it grows in the above mentioned foods it produces a poison which, when swallowed, causes acute internal disorders. This poison has no abnormal flavor, nor are there any other tell-tale signs to warn prospective victims not to eat such items of food."

"At present, the only known method of preventing the growth of these food-poisoning staphylococci in food is by refrigeration. In experiments on the relation of time and temperature to the growth of these staphylococci, it was found that, under favorable conditions, the poison was produced in 4–5 hr at 86 F, in three days at 65 F, but not in 7 days at 49 F, nor in 4 weeks at 40–45 F."

Food Storage

In every food service operation, proper storage facilities are essential in (1) preventing shrinkage, spoilage, and waste; (2) preserving the quality and appearance of foodstuffs; (3) making possible savings through quantity buying; (4) providing ample amounts of food for maximum volume; and (5) speeding up service from kitchen to table. The refrigeration problem in restaurants, therefore, is to provide the above essential facilities which in short

ROBERT A. KRAMER, Co-Author Chapter 40. Born 6/10/11 in Dayton, Ohio. Educated at Purdue University, BS, 1933. Formerly Process Engineer, Frigidaire Division, General Motors Corp., Dayton, Ohio, 1936–44.
Author of Application Data Section 6-R, "Refrign. in Restaurants," 1950.
Member, Amer. Soc. of Refrig. Engineers; Ohio State Professional Engineers.
At present, Sales Engineer, Frigidaire Division General Motors Corp., Dayton, Ohio.

PAUL P. LOGAN, Co-Author Chapter 40. Born 10/7/89 in Red Oak, Iowa. Educated at Army Industrial College; Army Subsistence School; Short Course in Food Technology, Mass. Inst. of Technology; Amer. Inst. of Baking. Formerly with the U.S. Regular Army, 30 yrs.; Retired as Colonel, QMC; Faculty, Army Industrial College and Army Subsistence School; Chairman, Provisions Committee, Federal Specification Board, 1936–46; Assigned to Chinese Army 1944–45 to study nutritional status of combat Chinese troops and prescribe new ration and rationing system.
Author of text books for Army Subsistence Schools; co-author of "Keeping Quality of Precooked Frozen Chicken a la King: A Bacteriological Evaluation of Hot and Cold Pacs."
Charter member of Inst. of Food Technologists; Member of Board of Governors of Refrign. Research Foundation; Member of Technical Advisory Council of Illinois Inst. of Technology. Awarded the Legion of Merit, U.S. Army.
At present, Director of Research, Natl. Restaurant Assn., Chicago, Ill.

means providing proper storage conditions for the various food products until it is convenient or necessary to make use of them. This is accomplished by controlling the temperature and moisture conditions primarily, but other factors such as air flow, initial condition of the food and the packaging or surface protection of the food must also be controlled to get optimum quality in foods held under refrigeration.

Storage conditions will vary according to the characteristics of the particular product and the length of storage, but if the storage space is kept under proper conditions the restaurateur will have fresh food on hand at all times with the assurance that their quality **will be unimpaired for a reasonable period of time.**

Generalities in refrigeration work are dangerous, but as a general rule, foods not frozen should be stored at temperatures between 32 and 50 F, and **the lower the storage temperature the longer the period of storage will be within the maximum storage possibilities of the product in question.** Current trends, however, are toward providing the optimum quality in foods and lessen the emphasis on maximum storage life.

In considering the important factors of temperature and humidity, it must be remembered that the restaurateur has two separate and distinct problems—long time storage where bulk or quantity lots of food can be kept refrigerated, and short time storage where many types of food can still be kept refrigerated but handled quickly and conveniently. **Long time storage in this connection is NOT to be considered the same as long time storage for wholesale operations** (as, for example, in a storage warehouse where foods are frequently held for periods approaching their maximum life) but rather a condition where foods are generally turned over every 24 to 72 hr. Short time holding conditions are exemplified in the chef's refrigeration or the salad boxes found in most restaurant kitchens. Differences in the long and short time applications are brought out in the subjects that follow.

Temperatures, Humidities and Storage Conditions

Table 1 shows refrigerated temperatures for long and short time restaurant storage for typical commodities such as meat, fruit, vegetable, etc., that are most commonly handled in restaurants. Storage temperatures as shown are probably the most important factor in the preservation of food and the data presented represents experience or customary limits usually prescribed for storage room temperatures and are not absolute or final. **Often more than one product will be stored in a cooler, in which case, a mean of the temperature for** each product, somewhere in the temperature range shown, would be chosen.

Just as different foods require different temperatures for good keeping, so do they require different amounts of moisture in the air. Too much moisture in the air will help accelerate the growth of bacteria and mold, causing sliming, discoloration and loss of flavor in some foods, while not enough moisture results in dehydration and shrinkage. **This requires a compromise in the design conditions for many storage rooms or an attempt to get a "happy" medium.**

Proper requirements of moisture, or relative humidity, could be expressed in definite percentages for all the food products shown in Table 1, but it is extremely dangerous to tie too closely to this factor alone. Other factors affect this one as the following example will prove.

A refrigeration application might be stated as requiring a 90% relative humidity to protect the foods against dehydration and shrinkage. But 90% relative humidity produced in a room with gravity cooling units may not produce the same results insofar as optimum food storage conditions are concerned, as 90% relative humidity produced with forced air cooling units. The additional velocity of the air over the food created by the forced air cooling unit tends to dry out the food more than when using gravity coiling. A simple analogy can be made. Every housewife knows that clothes dry more quickly on a windy day. This same principle applies to the use of forced air as opposed to gravity coiling for food refrigeration. Therefore, relative humidity expressed in percentages can be misleading from the standpoint of refrigeration application.

Table 1. Temperature and Humidity Conditions for Restaurant Storage Refrigeration

Product	Short Time Storage		24 to 72-hr Storage	
	Temp, F	Moisture	Temp, F	Moisture
Vegetables	36–42	Class II	32–36	Class I
Fruits	36–42	Class II	32–36	Class II
Meats (cut)	34–38	Class II	32–36	Class II
Meats (carcass)	34–38	Class III	32–36	Class III
Poultry	32–36	Class II	30–35	Class I–II***
Fish	35–40	Class I	35–40	Class I***
Eggs	36–42	Class II	31–35	Class I
Butter, cheese	38–45	Class I*	35–40	Class II–III**
Bottled beverages	35–45	Class IV	40–45	Class IV
Frozen foods			0– 5	Class II

Temperatures and moisture conditions shown above give customary restaurant practice. Some variations may be expected due to different varieties of fruits or vegetables and the growing conditions in different geographical locations. For complete and detailed information, including approximate longtime storage life, on all types of foods, refer to Table 1. "Storage Requirements and Properties of Perishable Foods" in Chapter 14 of the 1950 Edition of Refrigerating Data Book, ASRE. The U. S. Dept. of Agriculture's Circular #278 is another authoritative source for conditions for the longtime preservation of fruits and vegetables.
* If not packaged; ** If packaged; *** Freeze and hold at 0 F or below if held for more than 72 hr.

A more practical answer is found if relative humidities are considered in terms of overall moisture conditions in the storage area. To do this, refrigeration applications in Table 1, and elsewhere in this chapter, are divided into four general classifications, depending upon the susceptibility to loss of moisture of the foods being stored. These are:

Class I—such products as eggs, unpackaged butter and cheese, and most all vegetables held for comparatively long periods of time. These products require very high relative humidity because it is necessary to effect a minimum of moisture evaporation during storage.

Class II—such foods as cut meats, fruits, and similar products. These require high relative humidities but not as high as Class I.

Class III—carcass meats and some fruit, such as melons, which have tough skins. These products require only moderate relative humidities because they have surfaces whose rate of moisture evaporation is moderate.

Class IV—canned goods, bottled goods, and other products which have a protective covering. These are products which need only low relative humidities or which are unaffected by humidity. Products from whose surfaces there is a very low rate of moisture evaporation or none at all fall into this class.

It is the problem of the refrigeration engineer to class any product according to its moisture requirements and to design the refrigeration equipment to provide those conditions. **Where two or more types of products are stored in one refrigerator, a compromise favoring the product most subject to dehydration should be made.**

Table 1 shows the "class" or moisture conditions which should be designed for in all restaurant applications. Table 2 shows several practical examples of how the

Table 2

Type Product	Storage Temperature	Moisture Condition	Type Evaporator	Refrigerant Temperature
Vegetables	36 F	Class 1	Gravity	18–22°
Vegetables	36 F	Class 1	Forced Air	25–30°
Fruits	35 F	Class 2	Gravity	13–17°
Fruits	35 F	Class 2	Forced Air	23–26°
Cut Meats	34°	Class 2	Gravity	12–16°
Cut Meats	34°	Class 2	Forced Air	22–25°

proper design conditions of temperature and humidity are produced for different restaurant applications.

Unfortunately, relative humidity is one factor that cannot be simply controlled only by a switch. Desired moisture conditions must be obtained by properly designed modern refrigeration equipment. The choice of the correct differential between storage fixture temperature and the evaporating refrigerant in the cooling unit, to provide the proper balance in the system is the simplest, least expensive and most practical method to achieve this end.

Frozen Food

In addition to the fresh foods for which the above data applies, the modern restaurants of today are widely using many types of frozen food products. **Ice Cream has been known and accepted for many years.** Quality frozen products such as vegetables, fruits, fruit juices, meats, poultry, and fish have proven to be equal to or superior to the fresh products.

The latest research available indicates that frozen fruits and vegetables should be stored at approximately 0 F, especially if they are to be kept for periods of three months or longer. Above this temperature they will suffer appreciable losses of vitamin C and other desirable properties and at plus 15 F most frozen foods also lose their color, aroma and flavor. Organisms also grow at these higher temperatures.

Just as important as having 0 F in the storage area is the necessity for keeping the temperature as nearly constant as possible. Fluctuating temperatures above 0 F, which may be caused by poor design of the refrigeration system or the admittance of warmer products into the storage area, raise and lower the temperature of the frozen products, may cause damage to the product and may shorten its storage life.

Frozen foods should be properly packaged or wrapped, otherwise they desiccate rapidly and their storage life is materially reduced. If, however, unwrapped or poorly wrapped frozen products are being stored, attention must be given to moisture conditions as well as temperature.

Table 1 shows a Class II application for frozen foods. Although frozen foods are usually protectively wrapped and sealed it has been found that keeping the higher humidity conditions is a good safeguard against dehydration resulting from fluctuating temperatures. The higher humidities also protect unwrapped frozen foods or partially used and opened packages of frozen foods, a condition common in restaurants. Many fruit products for commercial use are packed in 30 lb tins. This type of container is moisture proof and humidity is not a factor. When frozen foods are properly wrapped and in good condition the humidity is not of importance.

Of course, **storage at 0 F or any other temperature cannot correct a poor product that has been damaged mechanically or physically in shipment or handling, or which was of inferior quality before freezing.**

Refrigeration Applications for Restaurants

Food, although of primary importance, is not the only subject for consideration in restaurant refrigeration. Generally speaking, public feeding installations require more different types of refrigeration equipment for their various needs than any other type of business.

It is difficult to set up a yardstick of refrigeration requirements which would apply to all restaurants since there are so many sizes and types of eating establishments and so many variable factors. Basic factors such as number of meals served; extent of menu; type of restaurant; location, etc., all determine the refrigeration facilities that will be required. The following classification of common applications of refrigeration, cover both high and low temperatures and should all be given consideration in restaurant refrigeration.

1. Cold storage of meats, poultry, fish, fruits, vegetables and dairy products
2. Storage for frozen meats, poultry, fish, fruits and vegetables
3. Water cooling
4. Beverage cooling
5. Manufacture and storage of ice cream, ices, and frozen desserts
6. Storage of chef's, cook's, baker's daily supplies

7. Storage of salads and salad materials
8. Making and storage of ice in bulk, cubes, or crushed form
9. Refrigerated display for cafeterias and grilles
10. Soda fountain and back bar refrigeration
11. Refrigerated storage of garbage

During the past several years, *American Restaurant Magazine* has conducted various surveys on the use of refrigeration. A checkup of all figures gathered in these surveys shows the following results:

Refrigeration Use	Per Cent Mechanically Operated	Average Number of Boxes
55.6% have Walk-in Coolers	94.6	2
All have Reach-in Refrigerators	88.4	2
41.0% have Service Counter	81.2	1
70.5% have Ice Cream Cabinets	All	1⅓
20.8% have Beer Dispensers	65.4	1
35.2% have Soda Fountains	All	1
46.4% have Beverage Coolers	64.0	1
53.0% have Water Coolers	71.2	1⅓

These findings apply to the medium and large volume restaurants, cafeterias and lunchrooms, of which there are approximately 40,000 places in the United States, each serving 15,000 and more meals per month.

Large Restaurants

The large restaurants with seating capacities of more than 100 will no doubt utilize all of the above classifications. They find it necessary to keep large quantities of provisions at all times and they also find it more economical and convenient to provide the specialty type of refrigeration equipment for making their own frozen desserts, candies, baked goods and ice. Water cooling, beverage cooling and soda fountains make up another part of the refrigeration required in large restaurants.

Small Restaurants

For the small restaurant owner, the refrigeration equipment manufacturer has provided the package type of refrigerators and cabinets which enable the smaller operator to have the advantages of refrigeration in many of the classifications shown above. Self-contained and portable equipment such as reach-in refrigerators, beverage coolers, water coolers, and ice cream cabinets are made in a variety of sizes and afford the smaller restaurant owner a flexible means of locating his refrigeration equipment where space is important. Additional demands in his business or expansion can be handled with additional packaged units.

Medium size restaurants with seating capacities between 50 and 100 may require one or two built-in coolers for storage purposes and also many of the packaged type or self-contained refrigerators and cabinets. Their needs will require many of the refrigeration applications shown in the listing above, but how it is applied will depend on the individual characteristics of the operation. The following description of various types of refrigeration equipment should serve as a guide for applying the equipment to any size of restaurant.

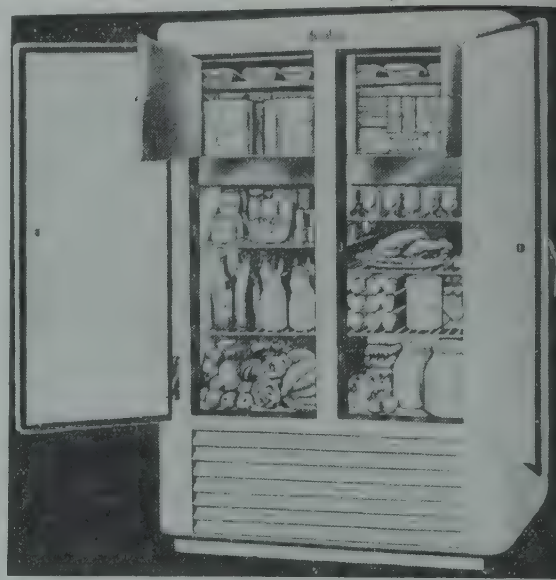
Refrigerators

A refrigerator is any portable refrigerated fixture of the reach-in or service type that can be used to store and preserve foodstuffs or other perishables, for short periods of time. In restaurants this type of refrigerator may only hold foods for a few hours before they are served or used in the kitchen, so it is a fixture for temporary refrigeration. They are commonly called reach-in refrigerators because of the ease with which products can be placed in or removed from the refrigerator, and also to distinguish them from the larger walk-in type of fixture.

Fig. 1 shows typical reach-in refrigerators as we know them today. They are completely self-contained with refrigerating condensing unit located in the bottom. The smaller cabinet "A," of approximately 20 cu ft capacity, has an ice making coil, while the five door model "B" has a forced aircoil and a net capacity of approximately 60 cu ft. Temporary refrigerated storage space is needed in every restaurant, and reach-in refrigeration has provided the proper type of equipment for chefs, bakers, for the pantry, for salad preparation and

Fig. 1. Typical Reach-In Refrigerators.

A—20-cu ft unit with ice making coil.



C—Two-temperature unit.

general service. All types of food and food products requiring refrigeration for short periods of time, can be stored in these fixtures and temperatures can be maintained between 36 and 40 F, except under conditions of extreme and heavy service.

The design of restaurant refrigerators should incorporate strong construction, lasting finishes, heavy hardware, serviceable interiors and dependable refrigeration. The same design of refrigeration that might give a lifetime of satisfactory service in a home, is not sturdy enough to stand the heavy duty use given it in a busy restaurant. Kitchen temperatures may go as high as 120 F, and frequent opening and closing of the doors and placing of warm foods in the refrigerator make this type of application one of the most severe in the whole restaurant.

Reach-ins that are located in the kitchen should be constructed with not less than 3 **in. of corkboard insulation** or equivalent. **Solid doors** should always be used on this type application. **Porcelain or stainless steel interiors** are preferable because they

B—60-cu ft unit with forced air coil.

D—Bakery refrigerator.

are durable, easy to clean and more sanitary. **Interior lights** are needed to help the user locate foods quickly. **Heavy duty hardware** and **commercial type adjustable steel shelving** either plated or stainless are necessary for the hard use that these refrigerators have to stand. Stainless steel angle slides are often used instead of the shelves when salad or dessert trays are stored in the reach-in.

Three types of **cooling coils,** all capable of maintaining temperature within the limits of 36 to 40 F, are available with most reach-in refrigerators. The selection of one or the other type depends upon the size of the restaurant. For the larger and medium size restaurant, a compact forced air cooling unit mounted against the rear wall or the ceiling of the refrigerator would be the most suitable. For the small restaurant or short order counter restaurant, a reach-in refrigerator equipped with an ice making coil the same as a household refrigerator, would be very practical. These coils have the capacity to make 15 to 25 lb of ice per freezing. Straight gravity type coils are also used in this type fixture.

Most manufacturers have standardized with reach-in refrigerators to the point of rating their size by the interior cubic content. They are made in a wide range of sizes, capacities starting from 15 cu ft and going to 100 cu ft.

Besides the variation of three different types of coiling available which was mentioned above, there are also many variations in types of doors and arrangement of doors. Solid door models are most suitable for larger size restaurants and glass door models would be advantageous from many angles in the counter type restaurant.

Bakery Refrigerators (See Fig. 1-D) or dough retarding boxes are a type of reach-in that would be used in restaurants that do a lot of their own baking. Besides the storage space provided in these boxes for storing perishable baker's ingredients they are also fitted with special tray slides which hold standard bakery pans.

Pass-through Type Refrigerators are cabinets that have two fronts so that they can be used from both sides. They are usually used in cafeterias or other places where there is a partition separating the kitchen from the cafeteria. Service can then be made on different foods and supplies that have been pushed into the refrigerator from the kitchen. Only a few manufacturers make this type of refrigerator as standard equipment.

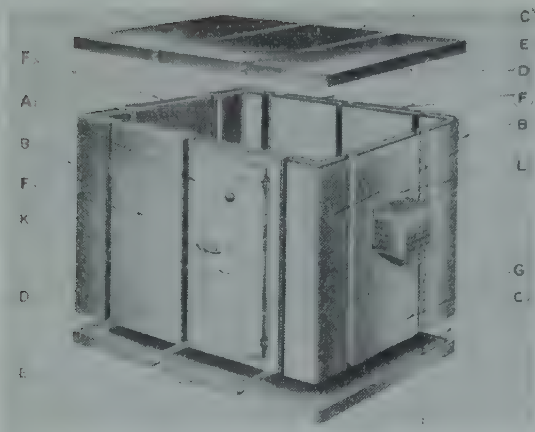
Two-temperature Refrigerators (See Fig. 1-C) are fairly new for restaurant applications but they have found a place in the small restaurant where some frozen foods are being used. As the name indicates, this refrigerator has two separate compartments; one, holding low temperatures for frozen food or ice making, and the other providing normal temperatures of 34 to 40 F. If no other storage space is available for frozen foods, this type of arrangement will provide a few cu ft capacity of zero storage in a cabinet that takes little floor space.

Walk-In Coolers

Another common form of refrigerator is the walk-in cooler which in general is a large refrigerated room having a door through which one may walk. Their function is for the storage of foods and food products for a longer period of time and in larger quantities than the reach-in refrigerator.

Good refrigeration practice dictates that these quantity lots of foods should be stored in separate rooms because they require different temperatures (See Table 1) and moisture conditions, and because odors from some foods are absorbed by others. The usual number of rooms required by the large restaurant is three; one for fruits and vegetables; one for meats and poultry; and one for dairy products. A fourth room for holding freezing temperatures could be added for restaurants using quantities of frozen foods. Small restaurants limited in storage room space find it necessary to have only one cooler but for the reasons given above this certainly does not give the best refrigeration conditions possible.

The size of the rooms depends upon the size of the restaurant and usually restaurants make the mistake of having too little rather than too much refrigerated space. Rooms that are smaller than 8 ft by 10 ft are not practical unless for some special use. The availability of supplies of fresh vegetables, fruits and meats also af-

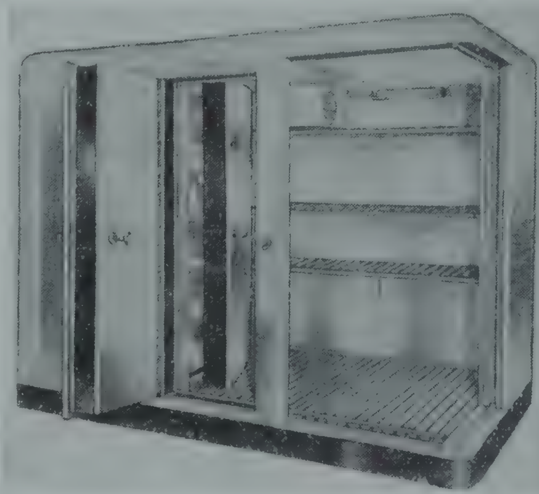


A

Fig. 2. Walk-In Coolers.

A (left)—Portable cooler showing sectional construction.

B (below)—Two-temperature model.



B

fects the number and size of coolers. Where products are received daily, the cooler is convenient and economical but for the restaurant that purchases supplies once or twice a week, the coolers are an absolute necessity and careful attention must be given to size.

Refrigeration equipment for walk-in coolers should be carefully chosen to give the best possible conditions of temperature and humidity for the various food products. Temperatures and moisture requirements shown in Table 1 should be designed for wherever possible. **When two or more products requiring different temperature and moisture conditions are stored in the same cooler, a compromise between the optimum high and low which will do the greatest good to the greatest number of products should be designed for.**

There are two distinct types of walk-in coolers used in restaurants—the cold storage room, and the cooling room or service cooler. Both types are for normal temperature applications and the refrigeration requirements and equipment are the same but the general construction and usage of the rooms are different.

The Cold Storage Room is a built-in type of fixture which often uses an existing building wall or walls as part of its construction. Because these built-in coolers are built to the needs and space limitations of each restaurant, they vary in size and shape and no standards can be set down. The best construction practices should be used for building walls, floors and ceilings. Accepted good insulation material at least three inches thick should be carefully installed in all the walls, floors and ceiling by a competent person. It is extremely important that all insulation be sealed by the proper application of an exterior vapor seal to prevent infiltration of any moisture. Doors should be rigidly insulated and of sufficient size to permit easy access of hand trucks. Heavy supports should be built into the room for installing rails, shelves and cooling units. Whenever possible cold storage rooms should be built to the floor level to permit easy access to trucks or wheeled racks.

The Cooling Room or Service Cooler (Fig. 2-A) is a walk-in fixture of portable, sectional construction. They are factory made products, as distinguished from coolers of the built-in type. Construction is sectional—the top, floors and walls being manufactured as separate components, shipped "knocked down" to the user and set up in the restaurant. Each section consists of a framework of wood, steel or other metals with interior ceilings, walls and floors also of wood or metal. Coolers are equipped with one or more walk-in doors to give the operator access to the interior. The interior equipment may consist of

meat rails and hooks, shelves, floor racks and other such devices. Most types of these coolers have the advantage of being expandable by simply adding extra sections which make them very flexible for the different sizes of restaurants. **Of course, when the size is increased the refrigeration components must be increased accordingly.**

A newer type of portable fixture has cooling units and condensing units mounted on one of the wall panels which makes up the construction of the room. This makes the complete room a self-contained piece of equipment similar to the reach-in refrigerator. Another variation of the standard coolers are two-temperature coolers which provide storage space at both freezing and normal temperatures (See Fig. 2-B).

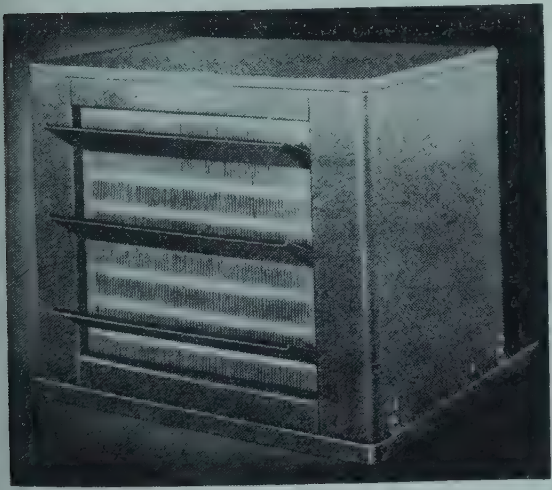
Construction of these restaurant coolers should be of the best, as they receive severe usage especially during rush hours. The hardware should be rugged, the doors well braced, and at least three inches of properly sealed insulation should be used in coolers for above freezing applications.

Refrigeration of Coolers

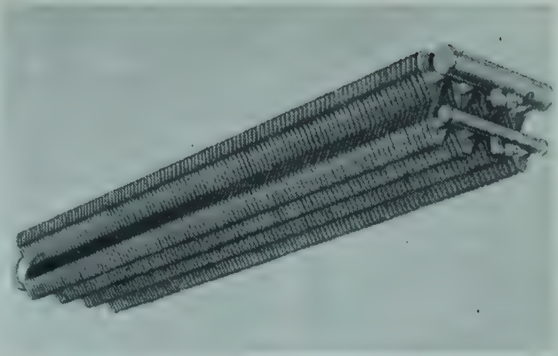
Careful consideration has to be given to the selection of the proper condensing unit and evaporator for every cooler installation. The many different types of applications that are encountered in restaurants, necessitate thorough knowledge of the foods to be refrigerated, the refrigeration conditions best suited for those foods and how to select and install the proper condensing units and evaporators. It should be handled by a competent refrigeration engineer.

Table 2 shows some typical examples of how the proper operating conditions of the condensing unit and evaporator will produce the best temperature and humidity conditions for restaurant applications.

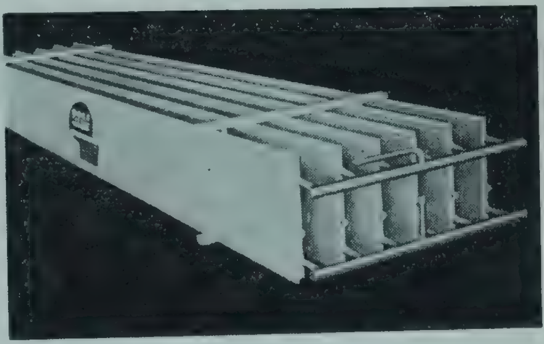
Fig. 3. Cooling Units.



A—Forced air unit or diffuser.



B—Finned gravity type coil.



C—Plate type gravity unit for installation on ceiling.

The condensing units must be capable of producing adequate capacities in Btu per hour to handle the maximum incoming heat loads and product loads at the refrigerant temperatures shown above. The evaporator or cooling unit must provide the same Btu per hour capacities to match the operation of the condensing unit when the unit is specified for a practical running time, resulting in a balanced refrigeration system.

Condensing units are rated by their ability to remove heat. Selection should be made upon the quality and dependability

of the unit. Evaporators are rated in the same manner but, since they are made in several different forms, their selection depends more upon the application or the conditions that must be met. Common practice today is to use either the forced air type cooling unit or the gravity type. If properly applied, there is little difference in results obtained.

Forced Air Units, or Diffusers, (Fig. 3A) are compact devices, completely self-contained in a metal housing ready for mounting on the ceiling or wall of a cooler. Their operation is a continuous cycle of drawing warm air from the fixture by means of a blower, forcing it over refrigerant coils, and then discharging the cooled air back into the fixture. Forced air coils have the advantage of compactness, take up little headroom and storage space, are simple to install, give more effective cooling, and provide more uniform temperature control in coolers that are heavily loaded. They may have the disadvantage of causing dehydration or drying out in certain products because of the rather high velocities of the air they move, if they are not carefully applied to the individual job.

Gravity Type Coils (3B) may be plain steel pipe coils or finned copper tubing coils fabricated in many shapes and sizes. Fins attached to the tubing give additional surface for the transfer of heat from the air to the refrigerant in the tubes and they are used in most gravity coils made today. Gravity coils provide a slower, quieter flow of air because it is air that rises and falls by natural connection. The standard, commercially sold gravity coils have the advantage of lower operating cost, more coil surface and less tendency to dry out foods which make them preferable for the storage of fresh meats and produce. Disadvantages are the size of the unit (they take up considerable storage space and headroom), and they are more difficult to install. For low height rooms of 7 ft 6 in. or less they are not practical, unless mounted on the side walls. Gravity coils usually require baffles to direct the air flow and drip pans beneath them to collect the condensation dripping from the coil surface. The latter can be eliminated in produce rooms allowing the moisture to drip on to the produce

D—Plate type gravity unit for use as contact freezing shelves.

and maintain high humidities which retains freshness in most fresh vegetables.

In the four different classes of foods previously indicated, and the examples given in Table 2, moisture conditions should be the controlling factor in the final selection of either of the two types of evaporators for a cooler. Moisture conditions in the cooler can be kept under reasonable control by the refrigerating engineer if careful attention is given to establishing the proper temperature difference between the air in the cooler and the temperature of the evaporator itself. The closer the temperature of the air and that of the evaporator, the less moisture is taken out of the air and the less dehydration takes place in the foods. For vegetables, fruits and meats in Class 1 or Class 2 applications, a large amount of evaporator surface should be provided and the temperature difference between the air in the cooler and the refrigerant in the evaporator should be as little as possible.

Smaller temperature differences should be used with the forced air type unit than with gravity coils. Table 3 gives practical design conditions for these two types of cooling units to conform to conditions specified in Table 1.

Table 3. Temperature Differences* in Walk-In Coolers for Four Classes of Foods

	Class 1	Class 2	Class 3	Class 4
Forced Air Cooling Units	6– 9° T.D.	9–12° T.D.	12–20° T.D.	Above 20° T.D.
Gravity Cooling Units	14–18° T.D.	18–22° T.D.	21–28° T.D.	27–37° T.D.

* "T.D." equal average fixture temperature minus average refrigerant temperature.

Defrosting

Defrosting directly affects the capacity of all types of cooling units, and therefore, is an important function of the refrigeration systems. Frost and ice accumulate on cooling units because the moisture in the air freezes on the evaporator surfaces. This prevents the heat getting to the refrigerant as fast as it should. Spaces between fins may fill up rapidly with frost or ice to the extent that air circulation is retarded and capacities further reduced.

In order to maintain proper refrigeration, it is necessary to get rid of this accumulation of frost or ice at regular intervals. With fixture temperatures of 35° and above, evaporators may be automatically defrosted by proper adjustment of low pressure controls supplied with condensing units by some manufacturers.

When temperatures lower than 35° are used, especially freezer room temperatures of 0°, some positive means of defrosting must be provided. This can be done manually by scraping the frost or ice accumulation from the coils; electrically by heating devices built into or under the coils; with water sprays over the coils; or with hot gas systems which circulate the heat from the compressor through the tubes of the coil. Automatic features can be had with the latter three methods at considerable increase in cost.

Another variety of automatic defrosting can be obtained on fixtures operating at 28 to 34 F by use of a time clock which will shut the system down at suitable and convenient intervals and return it to normal operation thereafter.

Freezers

Although this term is a misnomer for a frozen food storage room, it has become generally accepted as the room or cabinet provided to store frozen foods. If freezing is to be done as the name implies, an entirely different type of construction may be needed.

The cabinet type of freezer which has become standard equipment for retail food handlers has also found wide usage in restaurants for zero storage of small quantities of frozen food. These cabinets are usually of the self contained type and range in size from 4 cu ft to 30 cu ft capacity in standard sizes. Either vertical or horizontal models are available. This makes it possible for the user to get the type of equipment which will best fit his space. Ice Cream Cabinets (See Fig. 5-C) are especially suitable as a storage box for frozen foods because of their rugged construction and low temperature features.

Freezers can be either of the built-in type or the portable type. When built-in, they should be constructed the same as the cold storage room except that even greater care must be given to the application of good insulation. It must be sealed with a good vapor seal to prevent infiltration of moisture into the insulating material. Moisture in the insulation will reduce its effectiveness, increase operating cost and eventually it may not be possible to maintain fixture temperatures. For temperature of 0 F and below, a minimum of four inches of properly applied insulation should be used. Insulation thickness of six to eight inches is preferable. Lack of sufficient insulation may lead to sweating on the exterior walls of the fixture. Refrigeration equipment for the freezer differs from that used in the normal temperature walk-in cooler only in the type of evaporators used. For low temperature rooms, the problem of defrosting becomes very important and necessitates use of a different type of cooling unit. Forced air cooling units are satisfactory when equipped with electric, water,

or hot gas defrosting mechanisms to assure positive defrosting.

Gravity units are made in the form of plates for low temperature rooms. The plates (See Fig. 3) are installed on the ceiling of a room in a vertical position to hold 0° temperatures and also arranged as shelves around the walls of a room to provide contact freezing surface for freezing foods. Freezing of foods that might be necessary in restaurants can best be done on refrigerated plate surfaces to insure quicker and more thorough freezing of the food and thus minimize fluctuation of room temperature. Another precaution is to provide ample low temperature storage space so that the addition of warm food to be frozen or food that has raised to higher temperatures in transit and in handling will not raise the temperature of the storage space. If freezing is to be done in quantities and/or frequently, a separate freezing room or freezer cabinet is advisable.

Water Cooling

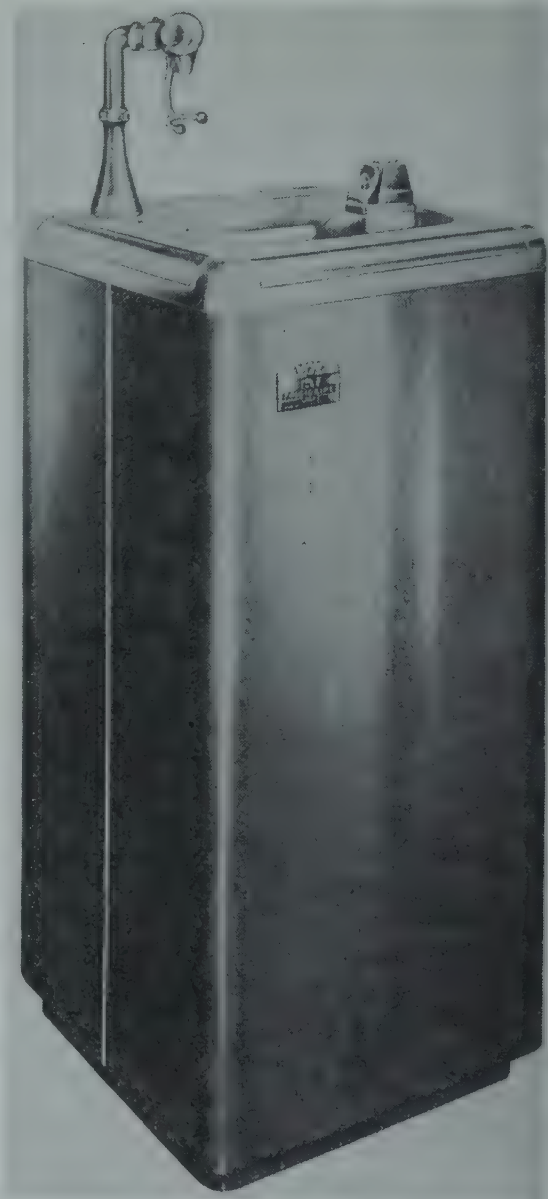
Restaurants of all sizes and types consider it of utmost importance and necessity to have drinking water for their patrons that is properly cooled. Many operators of successful establishments present the perfect glass of water as a promise of good things to come. Not only is the water presented to the patron when he first sits down but again just before leaving and the glass is usually kept filled as a token of gracious hospitality. Sparkling, chilled water, in a clean glass is the "engraved calling card" of almost all discerning operators.

Many different forms of refrigeration systems and equipment have been devised to handle the restaurant water cooling needs but generally they can be divided into two separate groups. Drinking water for restaurants—including those eating places where water is served to each patron by an attendant; and drinking water for cafeterias—including both public and private cafeterias where cold but not ice filled water is available to patrons through self-service. Usually trip-type faucets are used but bubbler fountains are not uncommon.

Regardless of the type of restaurant, the demand for drinking water usually comes in peak two-hour periods. Whether the peak comes once, twice or three times a day depends upon the individual restaurant, **but it is always a "peak."** Whether glasses are filled from faucets, or pitchers filled from faucets, the rate-of-flow is large and must be considered. **"Peak-requirements" and "large per minute-flow-rate" are the two fundamental capacity requirements that must be considered.**

Temperature reduction is, therefore, of prime importance. Most Americans want

Fig. 4. Water Coolers.



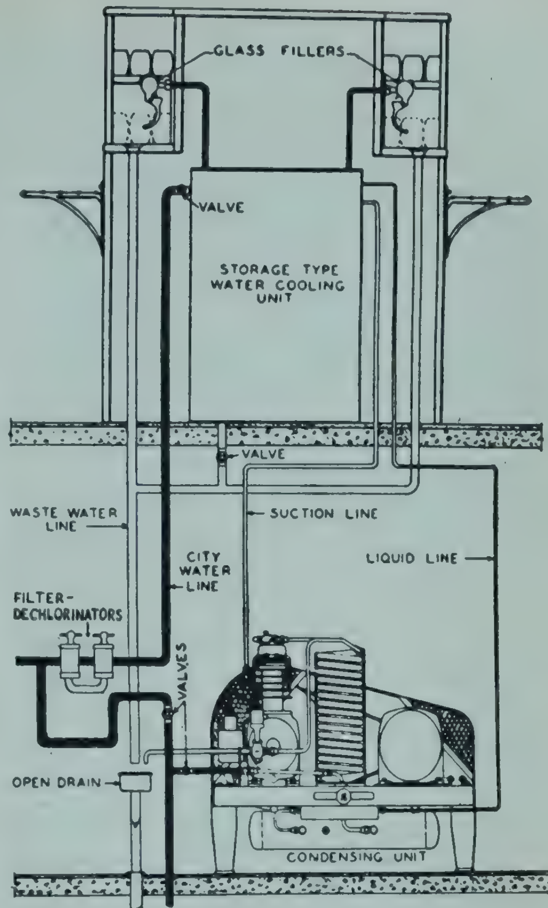
A—Combination glass filler and bubbler type.

their water served at about 45°. Appearance and taste of water are other important factors. Filters can be installed in water systems to remove iron rust and suspended matter and rectifier-dechlorinators added to remove chlorine taste and make the water sparkle.

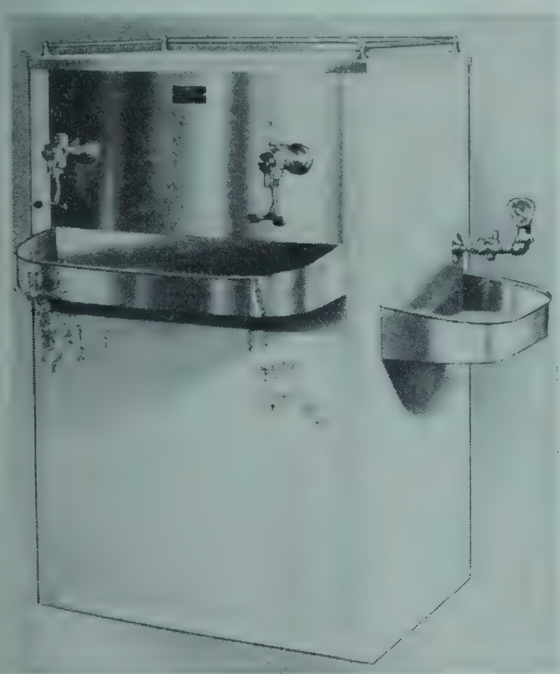
In restaurant applications, refrigeration engineers and restaurant specialists have long recognized and agreed that large storage of chilled water, ready and waiting to be withdrawn at fast rates, during one or two-hour peaks, is the proper way of meeting drinking water requirements. Relatively small size condensing units can be used with large storage low-sides. Off-peak operation allows them to build up large hold-over storage with which to meet peak demands. Long-cycle operation makes for efficiency, quiet operation and low operating cost.

Restaurant table service requires the filling of carafes or pitchers at filling stations which are generally a part of the serving pantry. They are sometimes supplied from circulating systems or remote coolers as shown in Fig. 4-C.

Unlike the restaurant where large storage of chilled water is required, those cafeterias that permit the patron to serve himself water, require more water cooling equipment of smaller sizes made accessible at several stations or locations in the cafeteria. These water coolers can be either the glass filling type or the combination glass filler and bubbler type shown in Fig. 4-A.



C—Design of a remote water cooler system.



B—Multiple drinking station.

Private dining facilities in office or factory locations are usually mass "eating places" where quick turn-over is a problem. Almost invariably such places are the cafeteria type and are often forced to operate in shifts allowing as little as 20 to 30 min per eating period. Large storage of chilled water is vital to successful operation.

Drinking water stations should be kept away from serving counters to avoid congestion. Speed up of service is accomplished by multiple drinking stations such as shown in Fig. 4-B and 4-D. Due to scattered locations of drinking stations they are generally of the self contained type

with water cooled condensing units and multiple fixtures. Equipping the back of the cooler with fixtures, the same as the front, giving due consideration to the increased capacity requirement is one way of speeding up the traffic in mass "eating places." Such installations are often referred to as "island" stations and adequate space must be allowed.

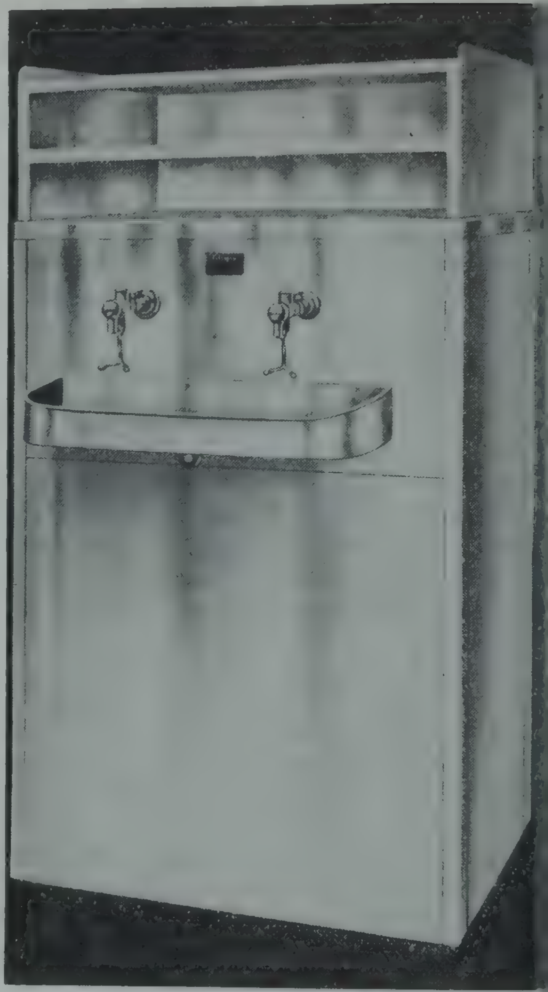
Shown in Table 4 are the amounts of water required per person and per seat for the various kinds of restaurant and cafeteria service.

Beverage Cooling

There is a big demand for cooled bottled beverages in food serving establishments. Particularly is this true in small restaurants, diners, and taverns. There are two types of beverage cooling applications used by food servers and requiring refrigeration —bottled beverage cooling and draught beer cooling.

Bottled Beverage Cooling. The increasing demand for properly cooled beverages and soft drinks has proven to be an important phase of the food server's business. Two general methods, wet storage and dry storage, are usually employed.

In the **Wet Storage** method, the bottled goods are immersed in a cold water bath. Since water is a good conductor of heat, this method provides most rapid cooling. The water bath is usually carried at a temperature of from 35 to 40 F and is refrigerated by a copper cooling coil or plate coils installed around the walls of the storage space. Most wet type beverage coolers are self contained with condensing units mounted in the base of the cabinet. Capacities range from 100 to 400-6 oz bottl[e] storage space. In some localities, sanitar[y] regulations prohibit the use of wet coolers.



D—Multiple drinking station.

The **Dry Storage** method depends upo[n] cool, circulating air to remove the hea[t] from the bottled goods. The air is usuall[y]

Table 4. Requirements for Various Types of Service

Service	Water Required	Recommended Temperature	Storage Required
Restaurant			
Table Service	.1 gal/person/hr	40–45°	Storage in gals should equal or exceed three-quarters of hourly requirements for all type of service.
Soda Fountain	.5–.75 gal/hr/seat	40–45°	
Sandwich Bar	.5–.75 gal/hr/seat	40–45°	
Diners	.5–.75 gal/hr/seat	40–45°	
Cafeteria			
Public	.083 gal/hr/person	40–45°	
Office-Factory	.1 gal/hr/person	40–45°	

circulated by a fan which forces the air over a fin type coil and distributes it throughout the cabinet. Air is cooled to temperatures of between 35 and 40 F. While somewhat slower in cooling, dry storing preserves the labels on bottles and eliminates the handling of wet bottles. Dry coolers are made in larger sizes than the wet coolers with capacities ranging from 100 to 1000-12 oz bottles. They make up for their slower cooling rate with more storage capacity. To be successfully used the coolers should be completely loaded at the end of the business day and also kept filled at regular intervals throughout the day.

It is common among most manufacturers to make these larger dry coolers available either as a self contained piece of equipment complete with condensing unit

Fig. 5. Miscellaneous Restaurant Refrigeration Fixtures.

A—Dry storage beverage cooler.

or as a cabinet only—easy to connect to a remote condensing unit. (See Fig. 5-A.)

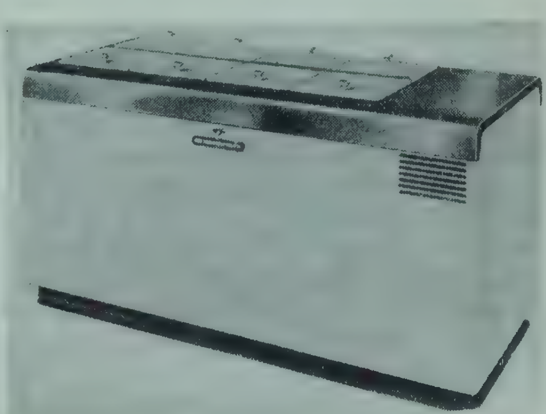
Draught Beer Cooling. Beverages very often have to be cooled in bulk as well as in bottles. While a number of these are special applications, the most common in restaurants is for keg beer. Certainly there is no beverage that requires more careful cooling because beer is a perishable the same as food. Draught beer is usually not pasteurized and must be kept cool to diminish the yeast activity.

Although beer may be held at the brewery at 35 F, there is considerable temperature rise before the beer reaches the dis-

B—Bulk ice maker.

pensing equipment. The handling of draught beer after it reaches the restaurant may involve three refrigeration problems —precooling (if the beer is delivered from the brewery warm), holding (after precooling, or after delivery if beer is delivered cold), and final cooling (from holding temperature to serving temperature).

Precooling and holding of keg beer is done in the walk-in type of cooler and the application offers no special refrigeration problem. Provision is sometimes made for the storage of cases of bottled beer in the same precooler. Standard compressors and forced air type of coils balanced to give temperatures of 45 to 50 F are most practical. Coiling should be specified to give



C—Ice cream cabinet.

higher relative humidities when wooden kegs are stored.

The final cooling of draught beer to serving temperatures of around 40 F can be done by many different types of fixtures whose selection depends upon the restaurant operator's preference. Instantaneous coolers of the direct expansion or water bath type have been incorporated in many different types of dispensing equipment. "Novelty boxes" which provide space for the kegs, as well as the final beer cooling coils are common in the smaller eating places.

In no case should the function of beer cooling and food storage be combined. Loads and storage conditions differ and it is not good practice from a sanitation standpoint.

Ice Cream Cabinets

One of the most universally used refrigeration fixtures in all types of restaurants is the ice cream cabinet. Made expressly for holding low temperatures, this type of cabinet is used to store bulk and package ice cream and many other frozen products. Restaurants commonly use them to store ice creams, sherbets and other types of frozen desserts.

Ice creams and sherbets are perishable foods. Due to the air which forms a portion of their volume, their structure requires that they be handled under proper and constant temperature conditions. Bulk ice cream is usually dipped and served to be consumed immediately; hence, has a definite temperature requirement. A serving temperature of about 10 to 15 F is usually desirable for most ice creams, but will vary with the composition of the ice cream, some requiring a lower temperature. The majority of ice cream below 5 F is very difficult to dip because it is frozen too hard. For these reasons, bulk storage at from 6 to 10 F is considered best practice. Such cream is suitable to dip and will quickly warm to a good tasting temperature. Sherbets, due to their increased sugar content, may be served equally satisfactory a few degrees colder.

Most package ice cream is stored at 0 to 6 F. Some, however, will require lower temperatures due to its composition. This allows a few degrees of extra initial refrigeration, allowing for a reasonable delay if properly handled before consumption.

Conventional ice cream cabinets such as the one shown in Fig. 5-C are made in many different sizes to fit the needs of different size restaurants. Storage capacities range from 10 gal to 60 gal. Ice cream cabinets can be either "self contained" or "remote," depending on whether the condensing unit is part of the cabinet or is to be remotely connected.

Ice cream cabinets also offer an ideal type of fixture for the storage of frozen food products. Frozen vegetables, fruits, and other items can be kept in this type of low temperature cabinet very conveniently and very near the point of use. They are designed and built for heavy duty service which meets the requirements of restaurants.

Ice Making

In all the applications of refrigeration equipment discussed thus far, the purpose has been either to preserve food or to improve or maintain the quality of beverages. Ice making is an application that goes back to the very basis of the refrigeration business. In many restaurants there is a demand for ice making and storage equipment in order to make such installations independent of any outside source of supply. Large restaurants and hotels are particularly interested in an ice maker with sufficient capacity for their special needs in order to provide greater freedom from the necessity of purchasing commercial ice in small quantities.

Many restaurants find that ice in sufficient quantities can be manufactured for much less than it can be purchased. Where ice makers are installed they will often pay for their cost in two to three years. Ice makers for these purposes are divided into two classes. First, those that make ice in bulk or block form; second, those making sized ice in small cubes or chips for use in beverages and water.

Bulk ice makers are built on the same principle used in the construction of large commercial artificial ice plants. (See Fig. 5-B.) They are made in different sizes and ice freezing capacities to match the re-

quirements of the restaurant. A storage cabinet type of fixture, they are available with capacities of 75 to 2000 lb of ice per day and sufficient cooling capacity is usually provided to freeze this quantity of ice in one day. They are of the indirect freezing type and employ a brine solution as the freezing medium. Ice is made in 25, 50 and 100 lb cakes. Although this type of equipment is more commonly thought of as only for the purpose of making cake or block ice, newer models of these bulk ice makers are provided with metal grid assemblies suitable for fitting in the ice cans to make ice in cube form.

Cube Ice Makers are divided into two classifications—ice making evaporators and automatic ice cube machines. Ice making evaporators are basically the same type as those used in domestic refrigerators except they are of larger sizes and usually built into special cabinets. They are of plate coil construction utilizing direct expansion refrigeration. The plates are separated so that ice trays fitted with cube grids can be placed between them for contact freezing. The cabinet type of ice makers are usually less than 200 lb capacity for 24 hr, make three freezings per day, ranging from 20 to 60 lb of ice per freeze.

The automatic ice cube maker, a device which before the war was only conversation, has now been developed and manufactured by several refrigeration companies. The few types of machines that have been offered to the public have had increasing acceptance by restaurants and other such establishments because they have been practical, labor saving and reasonable in cost. This should result in great strides being made by the refrigeration industry with this type of equipment in the near future.

This type of ice maker is built in a closed cabinet form which houses the complete assembly for making ice cubes, the condensing unit and also a storage section for holding a supply of ice cubes. Machines that have been developed so far have a range of capacities from 150 to 500 lb per day. In ice cubes this amounts to 1000 to 8000 cubes per day with the size of the cubes being different in the different makes of equipment.

There has been some controversy in the use of these automatic ice makers as to the relative merits of clear or opaque ice. As far as refrigeration value is concerned, there is no difference between clear and opaque ice, pound per pound. The controversy is based on the idea that clear ice is better because it looks more pure than opaque ice. This is not true, from a sanitary standpoint. The ice is opaque because there is air or mineral compound in it. Clear ice results primarily from elimination of air and minerals by agitation or stirring while freezing. Either type of ice is satisfactory from the patrons' standpoint.

Other Ice Making Equipment

Ice in either the block or cube form can be further processed into different types of sized ice by the use of mechanical equipment such as ice crushers. Automatic equipment is also available in both small and large capacity machines to produce cracked ice, snow type ice and special shapes of flakes, ribbons or cylindrical ice.

Other Refrigeration Fixtures

Salad Pans. Restaurants and cafeterias requiring self-service or display of salads, sliced fruits, desserts or other similar articles of food need refrigerated salad pans to preserve the condition and appearance of the food. A salad pan is simply an open pan type receptacle of proper shape and size in which salads can be placed. They are not usually made in any standard size or sold by fixture manufacturers but rather they are designed and built to specification by restaurant equipment suppliers.

There are several methods of refrigerating salads and desserts in salad pans: First, they may be placed on a pan which is chilled by refrigeration from beneath in the form of direct expansion evaporators of tubing or plate construction; and second, by the flooding of a refrigerated pan with water. The water may be allowed to freeze and the resulting ice form a pan upon which the salads and desserts are placed.

Display Refrigerators are sometimes installed in the dining room of grills or chop houses, for the storage and display of steaks, chops and sea food. They may also be installed in some quick service res-

taurants that do their short order cooking in plain view of the patrons. Standard display cases are six to twelve feet in length. They are either of the single shelf display type or a double duty type which has storage space in addition to the display section. These refrigerators are around counter height, with glass front and reach-in type service doors at the rear. Temperatures of 34 to 40° are desirable in these fixtures.

Back Bar Refrigerators are used in lunchrooms, luncheonettes and cafeterias for salads, cold cuts, fruit juices, and beverages. Under-counter refrigerated fixtures are used for the same purpose. Design temperatures are 40 to 45°.

Soda Fountains are another important unit which provide refrigeration for ice creams, syrups, whipped cream, bottled drinks and cold water. A complete luncheonette or counter food service is very often built around the modern soda fountain because they provide so many vital needs for that type establishment.

The soda fountain presents a multiplex application of four fixtures of widely varying requirements, all in the same unit package and generally connected to a single condensing unit. Ice cream storage, water cooling, dry storage, and syrup cooling are the usual four function sof a soda fountain. Where water cooling load is heavy it may be advisable to put a separate condensing unit on that part of the fountain.

Soda fountains are built in sizes based on the ice cream storage capacity in multiples of five gal. With an increase in storage capacity there is normally a corresponding increase in the size of the dry storage, water cooling capacity, and length of syrup rail. Sizes from 10 to 60 gal are most common.

Need for Refrigeration

Proof of the need for proper refrigeration in restaurants is found in the fact that **tremendous amounts of money are lost every year in actual food spoilage** and/or in food which has lost its sales value through deterioration in flavor, crispness, color or texture. Most of this is attributable to faulty or inadequate refrigeration. The final result which is perhaps greater is the concomitant loss of patrons and good will of customers who are served food made inferior in quality because of inadequate refrigeration. A summation of recent research efforts by the *American Restaurant Magazine* shows: "More than two and a half billion dollars is spent annually by food serving establishments for food purchases. We estimate that approximately 50% of this amount is represented in perishable foods such as meats, fresh fruits and vegetables, butter, eggs, milk, shortening, etc. We believe it is safe to say, considering the field as a whole, that approximately 5% of this expenditure in perishable foods is lost due to improper refrigeration."

This unfortunate but correctable condition exists in a substantial percentage of restaurants regardless of size or type. The refrigeration equipment manufacturers are now making more and better equipment for all restaurant applications. Through advertising and educational material they have helped to bring restaurant management and refrigeration suppliers closer together on the essential requirements for food storage. The importance of sound refrigeration engineering design, proper layout to facilitate convenient and economical operation, and adequate space to handle the requirements of the individual establishment cannot be over-emphasized. **A restaurant cannot have too much refrigeration.**

Operation and Care of the Refrigeration Equipment

The restaurant owner and those who use or maintain the refrigeration equipment in the restaurant, should be well acquainted with the operating characteristics and individual functions of each refrigerator and every part of the refrigerating mechanism. No matter how efficient and dependable the refrigeration equipment may be or how well the refrigerator itself is manufactured, it is necessary that it be used properly and given good care. Periodic inspection and maintenance should be made of all refrigerated boxes and operating equipment to see that proper temperature and the design conditions are being maintained. Accurate

thermometers should be placed conveniently in each refrigerated space so that a close check can be kept on this most important function of any refrigerator.

Care of Refrigerators. Employees should be trained to be good housekeepers and to keep the refrigerated fixtures in the kitchen and the back room up to the same standards of cleanliness as the fixtures in front of the customer. Refrigerators should be completely and thoroughly cleaned once a week to maintain good sanitary conditions and eliminate odors. A solution of water and a mild cleansing agent is both simple and effective.

Shelves and meat hooks and other accessory equipment should be kept as clean as the pots and pans in the kitchen.

Turn off all unnecessary lights inside of the boxes and be sure that automatic door switches are working properly. Unnecessary burning of lights takes extra current and also puts an additional load on the compressor.

Defrost ice making coils whenever frost builds up to pencil thickness. Remove heavy coatings of frost from the inside of frozen food boxes periodically. A small wooden paddle can be used in the frozen food cabinet.

During the warm humid days of the summer or in locations where humidities are always high, moisture should be frequently wiped from the outside surfaces of low temperature boxes. Moisture condenses on the colder surfaces of all refrigerators when there is a large temperature difference between room air and the refrigerator and also when the air is moisture saturated. This condition often exists in kitchens while cooking is in progress. Poor insulation may also be a cause of moisture condensation.

Employees should be cautioned against leaving refrigerator doors open. This one factor has much to do with holding proper temperature and humidity conditions on the inside of all fixtures. Warm and moisture laden air rush into open fixtures at every opportunity and can only be dissipated by longer running of the compressor. The moisture becomes an additional handicap when it freezes on the cooling unit and cuts down their efficiency.

Flush out all drains in fixtures to prevent an accumulation of slime or dirt. A solution of sal soda and water can be used and then flushed out with hot water.

Door seals must be kept in good condition to prevent excess heat leakage into the refrigeration. Wash the door seals frequently with mild soap and water to remove grease and dirt.

Keep boxes in good repair. Warped doors, inefficient door seals, broken glass or hardware should be replaced at once. Hinges, handles and latches should be kept oiled and tightened for good service.

Don't permit food scraps to accumulate in any refrigerator or cooler. Such scraps furnish a fine "nursery" for mold and bacteria and spread to fresh products put in the fixture.

Watch for rust spots on the metal liners or any metal parts of the inside. Clean such spots with sandpaper or steel wool and touch up with enamel.

Care of Refrigeration Equipment. Regardless of the type of fixture used in restaurants on the particular job it has to do, the system will have three basic parts: the condensing unit; the cooling unit; and the controls.

Condensing units of the belt driven type include the compresser body, an electric motor and a condensor. The motor, like any other motor requires periodic oiling and cleaning. Oil should be added according to the manufacturer's instructions. Cleaning of the external parts of the motor should be done with a dry cloth. Belts should be checked for evidence of wear on fraying and be replaced before they break. The condenser on air cooled compressors serves the same purpose as an automobile radiator. It should be kept free of dirt and dust by frequent cleaning with a brush. Boxes or crates should not be crowded around the condenser or in any way obstruct air circulation through the condenser. Some compressors are of the hermetically sealed type, in which the motor and compressor are entirely enclosed and require no maintenance at any time. When trouble develops in such units it is necessary to call a service mechanic.

Cooling units as previously discussed may be of several different types and many

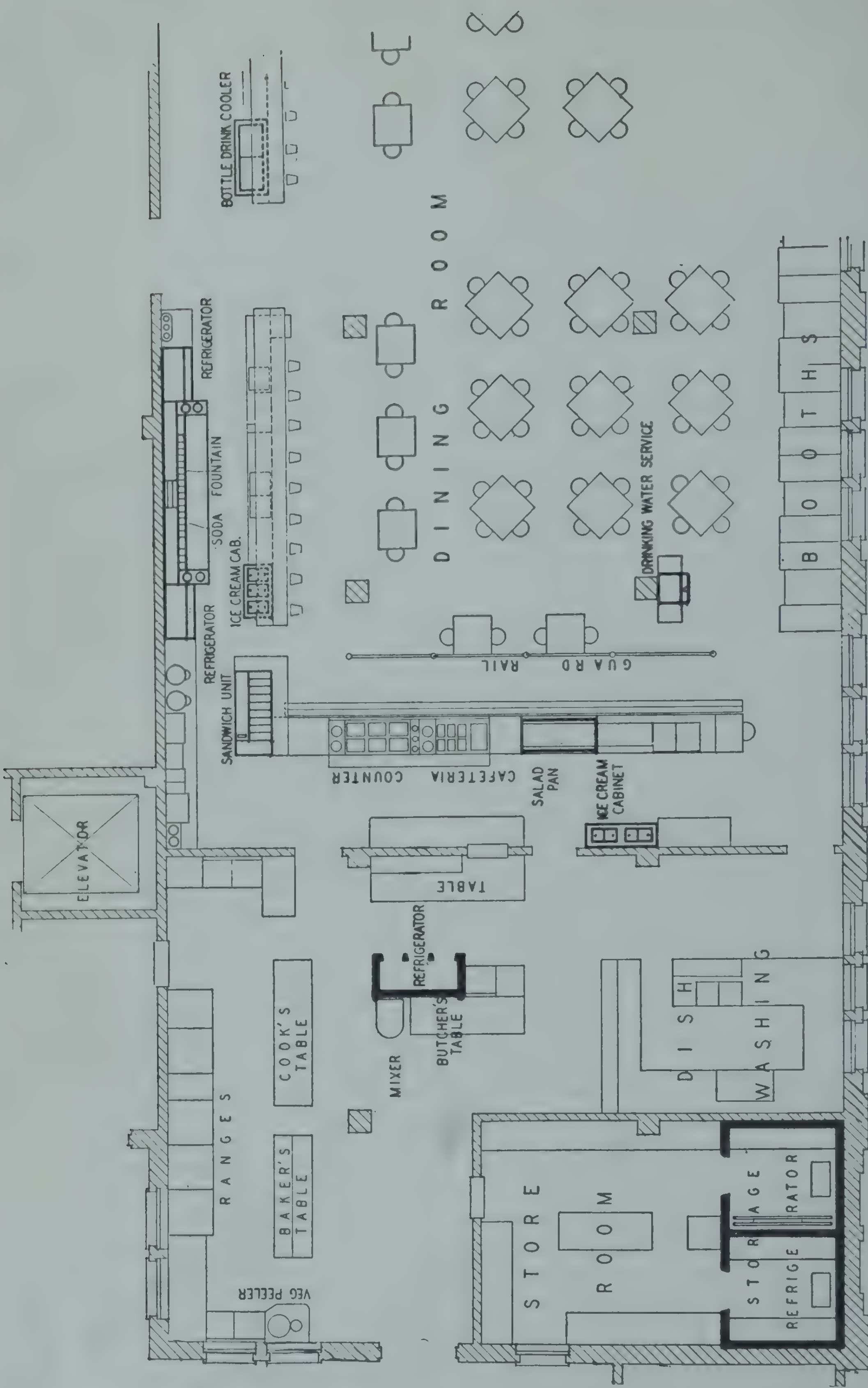


Fig. 6. Typical Restaurant Layout.

shapes and sizes. Gravity units used in fixtures above 34° should be checked weekly to see that they are defrosting properly. Pans and baffles should be kept clean and free of all restrictions. Be sure that refrigerant tubing going to or from the cooling unit is properly shielded to prevent damage. Boxes and barrels should not be piled close to refrigerant lines. With forced air cooling units care must also be taken to see that boxes or crates do not block air circulation. These units also have fan motors which require lubrication as recommended by the manufacturer. In low temperature installations defrosting may be done manually or by automatic devices, but it must be done frequently enough to keep the cooling units free of heavy formations of frost or ice.

Controls are the "brains" of all refrigeration systems. Without these various devices, automatic operation of the refrigeration system would not be possible. Valves, switches and thermostats should be carefully protected in locations that do not invite tampering. If they do not operate properly **they should be adjusted only by an experienced serviceman who understands how the system is designed to operate.**

Calculation of Loads and Selection of Equipment

The refrigeration applications for a restaurant that have been discussed so far cover a wide range of temperatures that are normally divided into two general groups: (a) high temperature or cooler storage, (b) low temperature or frozen storage.

It is desirable to divide the loads so that the condensing units may operate at the most efficient suction temperatures and maintain most uniform storage conditions. It is poor economy to impose a mixed load, that is, to load a cooler storage and a frozen food chest or ice cream cabinet, on one compressor, especially if the frozen storage load is less than half the total load. Under such an arrangement all the heat is removed at a very low suction pressure, and the power consumed per ton of refrigeration will be proportionally higher. A difficult problem of control will also arise, and it is generally better to provide two or more condensing units, one or more as may be required for high temperature, and one or more for low temperature refrigeration.

Where the refrigerated facilities include fixtures having a high product load, for example, where large quantities of warm fruits or vegetables, or large quantities of warm bottled beverages, must be cooled from room temperature to the cooler temperature, fixtures generally should be equipped with their own compressors. In general, water cooling systems should not depend on the same compressor serving other fixtures.

When refrigerators are located in kitchens, the ambient temperature may be as much as 15 to 20 F higher than normal outside temperature, and refrigerating machinery must be designed or selected accordingly.

Fig. 6 shows a typical restaurant. Following are the calculations of the **heat load** on the various fixtures, the **selection** of the condensing units and evaporators, based on use of one manufacturer's load tables, and the grouping of **equipment** based on principles discussed previously.

Example—List of fixtures, conditions, service required

A storage cooling room, 2-section, located in the storeroom; meat section, $8 \times 10 \times 9$ ft at 34 F minimum temperature; fruit, vegetable and dairy section, $8 \times 10 \times 9$ ft at 36 F minimum temperature. Only precooled meats are handled, necessitating no product load. Fruits and vegetables will require some cooling. Service would be classed as heavy. Insulation 4 in.

Kitchen service refrigerator, approximately 60 cu ft net storage capacity similar to Fig. 1-B. If separate smaller refrigerators are more practical there could be two 30 cu ft refrigerators provided. Temperatures of 36 to 40 F should be maintained in these fixtures under heavy or super-service conditions. These refrigerators are completely self-contained fixtures using $\frac{1}{2}$ hp condensing unit for 60 cu ft size and $\frac{1}{4}$ hp for 30 cu ft size.

Ice cream cabinet, 4-hole, in cafeteria line.

Salad pan (ice top), 5 ft long $\times 2$ ft wide, 3-in. cork insulation.

Drinking water service for the cafeteria line-up.

Dry beverage cooler, soda fountain line-up.

Ice cream cabinet, 6-hole, supplementary to soda fountain.

One 30-gal soda fountain with creamer section, dry storage section, syrup rail and water cooling for the 18 seats at the counter.

Sandwich unit in the soda fountain line-up, $5\frac{1}{2} \times 2\frac{1}{2}$ ft with 2-in. corkboard insulation.

Two back-bar refrigerators in soda fountain line-up, $3\frac{1}{2}$ ft long $\times 2$ ft wide with 2-in. corkboard insulation.

Cube ice maker, automatic type 400 lbs capacity. Located outside kitchen.

Design Conditions

Dining room temperature, 90 F maximum. Kitchen and storeroom are well ventilated, temperature, 100 F. Water temperature, 80 F maximum. Restaurant is open from 7:00 a.m. to 1:00 a.m. and does a very heavy luncheon and supper business. Breakfast business is light, and after theatre business light to normal. Seating capacity is 128.

Analysis of Installation—Heat loads, selection of equipment

1. The two-section **storage refrigerator** located in the storeroom will maintain approximately the same temperatures for the products stored in each section, and each will have service conditions similar and not out of proportion to the other. They can, therefore, be operated on the same condensing unit. In general, other fixtures should not be operated in multiple with storage refrigerators, since definite and uniform temperatures should be maintained. Storage refrigerators are usually the most important fixtures, because of size and the dollar volume of products stored.

The load requirements on the two-section storage refrigerator will run 171,000 Btu per day. The meat section will require 4500 Btu per hr (18 hr running time for condensing unit), and fruit, vegetable and dairy section, 5000 Btu on the same basis.

2. Forced air cooling units are suggested for both of these storage rooms. The produce room will be a Class 1 application requiring selection of a cooling unit for an average T.D. or with a rating of approximately 625 Btu/hr/1° T.D. The meat storage room is a Class 2 application operating on a 10° T.D. and a cooling unit should be selected which has approximately 450 Btu/hr/1° T.D.

A 1 hp water cooled condensing unit would have adequate capacity to handle the above boxes.

3. The **ice cream cabinet** in the cafeteria line is a small affair which will operate at a very low refrigerant temperature; it will not be advisable to multiplex this item. Ice cream cabinets are available as self-contained units in large volume production. A four-hole self-contained ice cream cabinet equipped with a $\frac{1}{4}$ hp air-cooled compressor would be suitable. See **Fig. 5.**

4. The **salad pan** will require a relatively low refrigerant temperature for its proper operation, although not so low a refrigerant temperature as an ice cream cabinet. The refrigeration load is relatively small—26,310 Btu per day, or 1460 Btu per hr for 18 hr. Since this type of salad pan requires a frost for ice formation, frequent defrosting is necessary. For the above reasons, it is advisable to handle the salad pan on its own condensing unit. This will permit shutting down the equipment to take care of the defrosting. A $\frac{1}{4}$ hp air-cooled unit to operate at approximately 3 F refrigerant temperature with 90 F air condensing medium, should be selected.

5. **Drinking water service** requirements for the **cafeteria** line-up are heavy, and peaks will be over an extended period of time. Consequently, water coolers attached in multiplex would upset the control of the other equipment. It is necessary to furnish only one water cooler of adequate capacity at the head of the cafeteria.

Water cooling for the soda fountain section will be taken care of by the fountain itself. Had the requirements for the soda fountain section been unusually heavy, due to an unusually large number of stools or high water temperatures, it might have been necessary here to furnish an additional water cooler at the counter. Had this been the case, it would have been possible to put the two water coolers on one condensing unit.

The water cooling load for cafeteria serv-

e should be based on .083 gal per person, ssuming three persons using each chair er peak hr. In unusual cases the water ooling load amounts to $\frac{1}{3}$ gal per chair per r. For this particular installation the waer cooling equipment should be selected n the basis of cooling 32 gal of water per r from 80 to 40°. For the peak demand, it ould be desirable to have a storage of aproximately 24-gal capacity. A $\frac{1}{2}$ hp waer-cooled unit would be required for a eak capacity of 40 gal of water in 2 hr (2×32-24). The unit capacity required mounts to $40/2 \times 333 = 6660$ Btu per hr t a 28 F refrigerant temperature and 80 F ondensing water.

6. **Dry Beverage Cooler.** This type of xture operates at a high refrigerant emperature, with abnormal service conitions and heavy loads. It is seldom conected in multiple with other equipment. This type of fixture is also usually available s a self-contained unit.

This equipment consists of a self-conained bottle cooler equipped with a $\frac{1}{4}$ hp ir-cooled condensing unit, having a storge capacity of approximately 12 cases of 2-oz bottles or 16 cases of 6-oz bottles. See **ig. 5-A.**

7. **Ice Cream Cabinet,** 6-hole. While it vould be possible to connect this ice cream abinet with the creamer section of the oda fountain, because of the similarity of emperatures, the self-contained unit has een selected on account of the availability of this type of equipment. It also provides a safety factor in the layout in the vent of any service difficulty. The equipment selected consists of 6-hole, doublerow, self-contained ice cream cabinet quipped with a $\frac{1}{4}$ hp air-cooled condensing nit.

8. The 30-gal **soda fountain** consists of a 0-gal creamer section, a dry storage comartment and syrup rail equipped with the ecessary evaporators and control valves. The equipment which provides the refrigeration for the dry storage compartment lso includes coils for the cooling of plain nd carbonated water. Although there is a vide variation of temperatures in this type f fixture, it is satisfactory to operate on ne condensing unit. Occasionally an additional fixture, such as a back-bar refrigerator or sandwich unit, may be hooked on also. In this case, inasmuch as there are an additional sandwich unit and two back-bar refrigerators, one condensing unit will be selected for the soda fountain only. The estimated refrigeration load for the soda fountain, exclusive of the water cooling load, is 932 Btu per hr for 18 hr running time. This estimate is based on maintaining approximately 8 F in the creamer section and 40 to 45 F in the storage compartment.

Water cooling for the 18 stools at the counter will vary from $\frac{1}{3}$ to $\frac{1}{2}$ gal per stool per hr at peak requirements. The carbonated water cooling requirements ordinarily will amount to 25 percent of the plain water requirements. The maximum or peak load water requirements would, therefore, be $\frac{1}{2} \times 18 \times 1.25 = 12$ gal per hr.

The water cooling systems employed in the fountains are designed to permit an ice build up on the refrigeration coils to take care of peak demand loads over a 1 to 2-hr period. It is, therefore, unnecessary to provide capacity to meet the peak load water cooling requirements. The condensing unit is selected to meet the heat leak requirements of 932 Btu per hr, plus one-half of the peak water cooling requirements (6 gal per hr) which, when cooling from 80 to 40 F, amounts to 1998 Btu per hr.

It is necessary to select the condensing unit on the basis of the lowest refrigerant temperature required for the system, which would be the creamer section of the soda unit. A $\frac{1}{2}$ hp water-cooled unit having a capacity of 2930 Btu per hr when operating at a $-15°$ refrigerant temperature, which is required for the average fountain, would be selected. Condensing units are operated by thermostat control for low temperature portions of such systems where uniform temperatures should be maintained. A low pressure control electrically connected in parallel with the thermostat operates the condensing unit when refrigeration is required for the water section.

9. The $5\frac{1}{2}$ ft **sandwich unit** and the two $3\frac{1}{2}$ ft **back bars** in the soda fountain line can be multiplexed on one condensing unit. Design conditions for these fixtures is 90 F ambient temperature, 40° fixture temperature for the sandwich unit and 45° fixture temperature for the back bars. The service

would be classed as heavy but the maintenance of uniform temperatures is not an absolute essential. The fixtures will be equipped with the necessary evaporators of the direct expansion type, but in small fixtures of this kind it is quite difficult to supply evaporators which will permit their operation at refrigerant temperatures higher than 7 to 11 F.

The refrigeration load for the two back bars amounts to 15,330 Btu per day or 850 Btu per hr. The refrigeration requirements for the sandwich unit amount to 22,200 Btu per day or 1230 Btu per hr. A $\frac{1}{3}$ hp air-cooled condensing unit should be selected, operated at a 7° refrigerant temperature with 90° air.

The back bars are ordinarily operated at a lower refrigerant temperature than the sandwich unit, but both may be directly connected to the same condensing unit. The sandwich unit would be connected to the condensing unit through a control valve.

10. Automatic cube **ice makers** with capacities up to 400 lb of cube ice per day will fill the needs of this size restaurant. The equipment is in cabinet form and completely self-contained with condensing unit. It could be located in the store room or adjacent rooms.

11. Not shown as part of the restaurants' present equipment, and purposely so, are facilities for storing frozen foods. This problem is one that many restaurants are facing today and facilities must now be added to most modern restaurants to handle the popular frozen products, such as vegetables, fruits, fish and fruit juices.

In the example shown, low temperature storage space is available in any of the ice cream cabinets but this space is probably not sufficient now for its intended purpose. The simplest and most economical way for restaurants of this type to meet this situation would be to provide an additional ice cream cabinet or other type of chest design low temperature cabinet and locate it in the store room or another spot close to the kitchen. 15 cu ft capacity should be sufficient.

Acknowledgment is made to the following persons for their contributions and helpful criticism:

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Dr. M. E. Pennington, Consultant
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National Restaurant Association Equipment Testing Committee

Bibliography

The reader is referred to the following Application Data Sections (published by ASRE, 40 W. 40 St., New York 18, N. Y.) for additional information on specific aspects of restaurant refrigeration:

ADS 11—Refrigeration Load Calculations
ADS 14—Air Conditioning in Restaurants
ADS 20—Refrigeration in Retail Beer Dispensing
ADS 27—How to Figure Refrigeration Insulation
ADS 31 and 31A—Refrigeration for Self-Contained and Remote Drinking Water Cooling Systems

Also see chapters on foods sections I through III and chapter 37 this section.

If you searched this chapter for something which was not found in it, please let the editors know.

41. PORTABLE COOLING SYSTEMS

THE portable refrigeration referred to here is that used overseas by the armed forces in World War II, consisting mainly of the following items or facilities:

1. Refrigerated warehouse, prefabricated, 600, 1800 and 3200 cu ft
2. Refrigerating machinery unit for warehouse
3. 150-cu ft walk-in refrigerators
4. 25-cu ft chest-type and 50-cu ft reach-in field refrigerators
5. Portable ice plants.

The conditions of warfare called for entirely new types of food preservation facilities. Gasoline engines were depended upon to a considerable degree. Since engineers have previously only dabbled with gasoline-powered refrigeration, the growing pains suffered through this development may yield a heritage for postwar users.

Design Considerations

These machines were primarily intended for use in advanced and isolated bases having no electric power source. After exhaustive tests in active service, the four-cylinder, four-cycle, liquid-cooled gasoline engine was pronounced best adapted to field usage for larger units. The single-cylinder, two-cycle engine was used on smaller units (25 cu ft), as well as a portable cream freezer. All these required a great deal of maintenance in the field.

Lack of an assured water supply in many areas to be occupied by our forces led to the choice of air-cooled condensers, operated in ambient temperatures as high as 130F. Perfect condensation at this temperature would produce a minimum pressure of 205 lb per sq in. with Freon-12; 250 was set as the limit, and 235 or better produced. A glance at **Table 1** will show why economy and efficiency were passed up in favor of a wide operating range.

GEORGE W. SHUBER, Author Chapter 41. Deceased. No biographical data available.

These **temperatures** have been recorded: Sand in the deserts, 160 F; metal in airplanes, 200 F. The world's highest atmospheric temperature was found in Aziza, Libya, North Africa. The highest mean temperature is at Massarra, Eretria, Africa, 80 F. The highest recorded in the U. S. A. is 134 F at Death Valley, Calif. Reports have been received of unofficial temperatures as high as 150 F in Libya and around the Red Sea. The highest practical wet bulb is about 88 F.

Ruggedness, as well as light weight, is a desirable objective; each unit piece, whether a complete facility or a section of a warehouse, was, before acceptance by the procuring agency, subjected to a "drop-test," and this test became the deciding factor between lightness and sturdiness. As an example, the 150-cu ft portable refrigerator was loaded with 4200 lb of sand in bags, one end supported on a fixed dunnage placed on the ground, the other end raised 48 in. from the ground, and allowed to drop. This gave the equipment a more severe shock than it would probably receive in sliding off the platform of a truck.

Complicated mechanisms were unde-

Table 1. Climatic Extremes for Portable Refrigerators

Location	Maximum, F recorded	Minimum, F recorded
North America		
Alaska	100	−78
U.S.A.	134	−66
Europe		
Italy	114	4
U.S.S.R.	110	−61
Asia		
Arabia	114	53
China	111	−10
India	120	−19
Iraq	123	19
Africa		
Algeria	133	1
Egypt	124	31
Libya	136	33
Tunisia	122	28
Australasia		
Australia	127	19
Solomon Islands	97	70

sirable, for these facilities were often in the hands of untrained men. All contractors were obliged to furnish technical manuals with their equipment. These manuals contained not only a complete story on operation, maintenance and spare parts, but also courses in fundamental refrigeration, suitable for use in training schools. For example, TM9094, a book of 351 pages, 9 in. by 6 in., carried more than 200 photographs and charts. Other manuals pictured assemblies broken up into component parts in the correct sequence for dismantling or assembling.

In most instances no one contractor was able to meet the delivery demands of the using force regarding any one facility. This resulted in an attempted **standardization** of design, to permit mass production simultaneously by several contractors and

Table 2. Prefabricated Warehouse Dimensions

No.	Length, outside ft-in.	Floor area, sq ft	Volume, cu ft
1	9-8	95	620
2	24-4	276	1,800
3	43-6	505	3,200
4	93-4	1,092	6,900

interchangeability of parts. In one case three manufacturers furnished centrifugal blowers to three contractors producing the refrigeration unit for the prefabricated refrigerated warehouse. These blowers, while performing the same function, were not interchangeable, but, by including properly designed shrouds and supports, component assemblies were produced that were interchangeable. These were listed as parts.

Exports before the war were not subjected to the hazards of military shipment and storage. We sent machinery overseas, protected by paint, grease or other coating, crated and loaded in a comparatively dry hold. Upon arrival this machinery had been uncrated, cleaned, erected and placed in service. Now we were forced to make shipments in excess of, and long before, actual requirements. Ships were loaded to capacity plus deck loads. Convoys were large, slow and not well protected. A great deal of the equipment reaching its destination was useless from corrosion. An idea of the magnitude of the shipping problem may be obtained from the following: One contractor, using about 200 employees in the assembling of a certain item, was obliged to employ 40 more people and about 1200 sq ft of floor space for export processing.

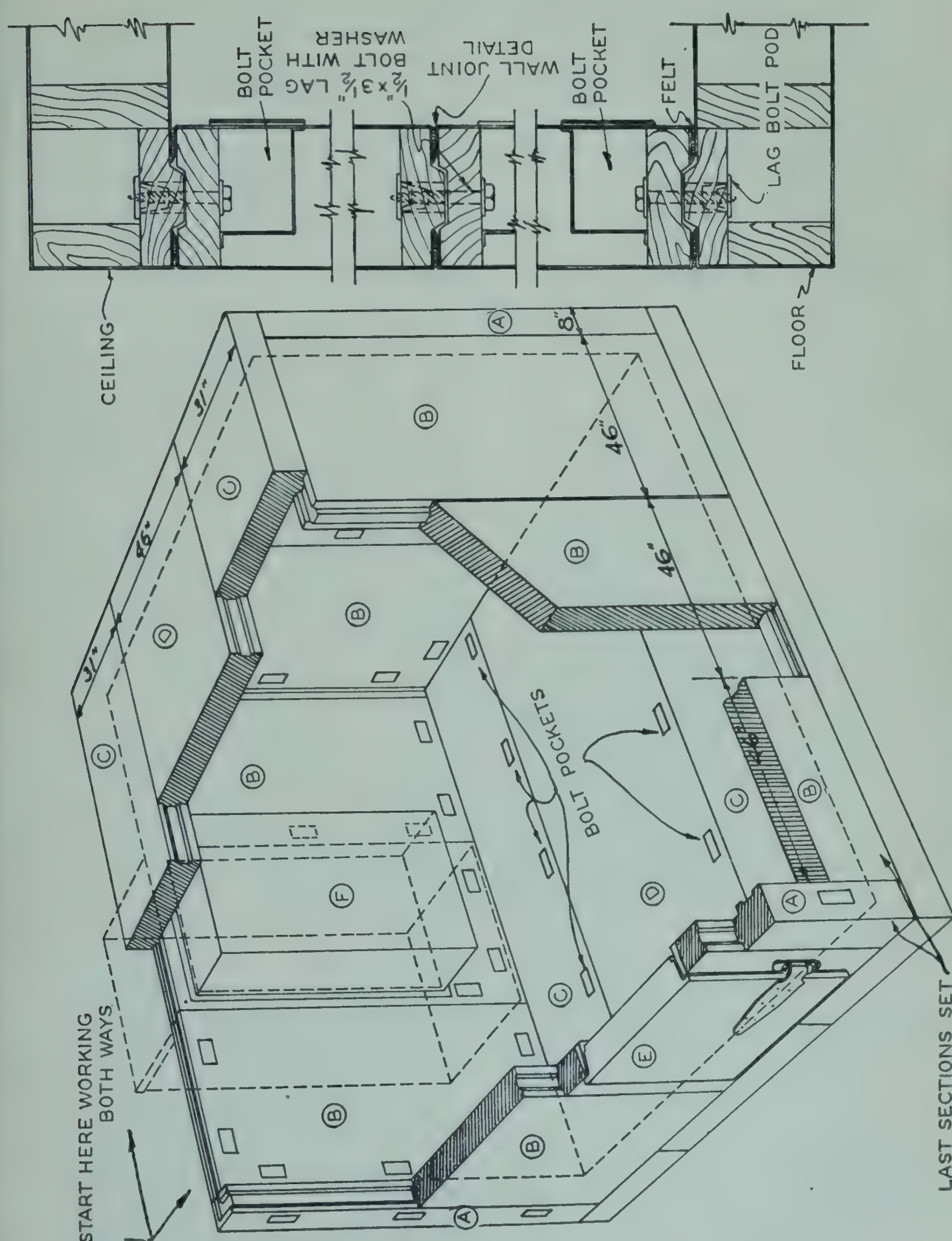
Refrigerated Warehouse, Prefabricated

The above nomenclature describes the Army self-sustaining storage facility requiring no additional building to withstand the elements. The Navy has a similar item called the "pre-fabricated, portable, knock-down refrigerator," while the Marine Corps designation is "refrigerator, sectional, walk-in type." The following special features were sought:

1. Portability, to permit movement with the using military force.
2. Flexibility as to size. Foodstuffs are supplied by refrigerated trucks or boats operating either from debarkation or central base depots. The warehouse may be called upon to carry a 30-day supply for a few men or to take care of larger groups on some other supply schedules.
3. Operation at 10 F for frozen products and 35 F for fresh perishable foods.

Late in 1942, development engineers from the Army, Navy, and Marine Corps met with design engineers from industry and standardized this "warehouse" in four sizes having the common outside dimensions of width, 12 ft 10 in. and height, 7 ft 6 in. The outside lengths varied as in **Table 2.** One sectional partition was shipped with the No. 2 warehouse, two with the No. 3, and 5 with the No. 4, which permitted either two-temperature operation or segregation of products.

Fig. 1 is a cut-away perspective of the No. 1 warehouse which is typical of all sizes. (See **Table 3.**) Ordinary 2×6 in. lumber is used for the framing of all sections, except the corner posts. Semi-rigid or batt-type insulation is placed between



Figs. 1 and 2. Typical Detail of Wall Section at Floor and Ceiling Joints, Prefabricated Refrigerated Warehouse.

the 20 U. S. gage galvanized, inside, and the 18 U. S. gage black sheet steel, outside. Type E and F sections are interchangeable with type B section, which allows the door or refrigeration unit to be located at any desired side or end wall position. Type E

Table 3. Dimensions of Section of Prefabricated Warehouse, in.

Section	Name	Length	Width	Height
A	Corner post	78	8	8
B	Std. side wall	78	46	6
C	End floor or roof	154	31	6
D	Center floor or roof	154	46	6
E	Door frame	78	46	6
F	Evaporator panel	78	46	6

Dimensions above include gasket attached to male part of joint.

sections include standard, single-seal, infitting type cold storage door. Type F sections are made with a clear opening of 55 by 38 in., to receive the insert panel built into the refrigeration unit. Floor racks of 44-in. × 11-ft 9-in. sections are made a part of each warehouse. Each section is formed of 1-in. by 2¾-in. hard wood slats fastened to hard wood battens of 1¼ in. by 2¾ in. spaced on centers not more than 18 in.

Table 4 gives bills of material for the four warehouses with crating data. Since .02 sq ft of floor space is required for each ration stored, the capacity of these warehouses figures out from **Table 5**: No. 1, 4750 rations; No. 2, 13,800 rations; No. 3, 25,250 rations; No. 4, 54,600 rations.

The gross weight of the No. 1 warehouse is about 7600 lb, but the heaviest crate weighs only 1165 lb. The refrigeration unit weighs 3230 lb crated. Seven untrained service men who had never seen this facility before were given maintenance manuals for instructions. Assembling, from crated material to operating warehouse, was accomplished in 7 hr by these men, a proof of the clarity of the instruction manuals.

Refrigerating Machinery Unit for Warehouse

The first specifications called for a capacity of 9150 Btu per hr when operating on the 10 F cycle, with Freon-12 and forced air circulation, powered by a heavy duty gasoline engine. Several contractors furnished their units with a single-cylinder air-cooled engine. This type engine was later rejected, in favor of the four-cylinder liquid-cooled engine to eliminate heat and vibration. New units were tested by the Engineer Board at Fort Belvoir for mechanical adaptability to field service (rather than for capacity). Field service demanded simplicity of design, accessibility to component parts and mechanical sturdiness. Carefully calibrated gages showed pressures and thermocouples registered temperatures at the following points: Gas entering, and liquid leaving condenser, air entering and leaving condenser, liquid

Table 4. Bills of Material for Prefabricated Warehouses

Warehouse Number	1	2	3	4	
Parts	Quantity required				Packing method
Refrigeration units	1	2	3	6	1 unit per crate
Type A corner post sections	4	4	4	4	4 sections per crate
Type B sidewall	8	14	22	42	2 sections per crate
Type C end floor or roof sections	4	4	4	4	2 sections per crate
Type D center floor or roof sections	2	10	20	46	2 sections per crate
Type E door sections	1	2	3	6	1 section per crate
Type F insert panel sections	1	2	3	6	1 section per crate
Type G floor racks	2	6	11	24	2, 3 or 6 racks per crate
Type H bottom partition	0	1	2	5	1 bottom and
Type I top partition	0	1	2	5	1 top section per crate

Table 5. Composition of Theoretical Perishable Ration for Overseas Troops

	lb/day
Frozen packaged boned beef	0.50
Ham, bacon, and bologna	0.16
Butter	0.13
Shell eggs (one each)	0.13
Potatoes, onions, citrus fruits	0.70
Perishable fruits and vegetables	0.70
Total	2.32

and vapor entering and leaving the heat exchanger, liquid entering expansion valve, evaporator temperature, air entering and leaving evaporator, and suction at compressor, as well as the water and air in and out of the radiator.

Load calculations prescribed in the 1942 Basic volume of the ASRE Data Books, Chap. 31, were used in determining the capacity of the required unit. The actual leakage load was then measured by adding heat inside the compartment until the temperature ceased to rise or leveled off at a temperature difference similar to that maintained in the cold test. Floor fans with vertical discharge were used to obtain uniform temperatures, and to simulate the heat transfer action caused by wind velocity. A hot room was later provided.

After equilibrium was approximated, the test was continued for 12 hr before readings were taken. By this means an actual

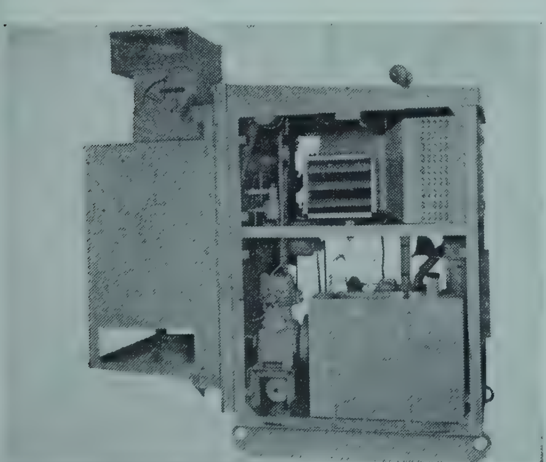


Fig. 3.

flow of 0.090 Btu per sq ft per hr per degree was measured, against a computed value of .069. The actual leakage load established by this test was considerably higher than that estimated, due to insufficient allowance for joint leakage. To simulate field usage the warehouse was erected by untrained troops. This increased load, plus reports of higher ambient temperatures encountered, necessitated the new and final specifications calling for:

1. 12,000 Btu per hr with 10 F air at evaporator, 85 per cent rh, evaporating temperature 0 F, and unit operating in an ambient of 110 F with safe operation in 120 F ambient.
2. Full automatic control at either 10 F or 35 F box temperature.
3. Capacity determined by ASRE Standard 25–42, "Rating and Testing Forced-Circulation Air Coolers for Commercial and Industrial Refrigeration."

Instructions for the warehouse erection call for the placing of timber runners on the levelled ground, with two of these runners extending beyond the warehouse to support the unit. Two men can move this unit on rollers and pry on to the skids until the gaskets on the insert panel are flush with the outside of Type F Section. After securing four corner clamps the operator pours a separately-packed electrolyte into the storage battery, removes any export processing from exposed parts, charges with gasoline, oil and water and throws the switch. This is a three-point switch for automatic, off, and manual.

Fig. 3 shows the left side view with panels removed. The blower has double suction, one side drawing air in through the condenser and the other removing air from the compartment in excess of that drawn through the radiator by its disc type fan. This is done not only to insure complete evacuation of the heated engine compartment air, but also to draw in fresh outside air through all cracks and openings. One opening just back of the receiver between the evaporator plug panel and the floor of the compartment is about 2 in. high and extends from corner to corner.

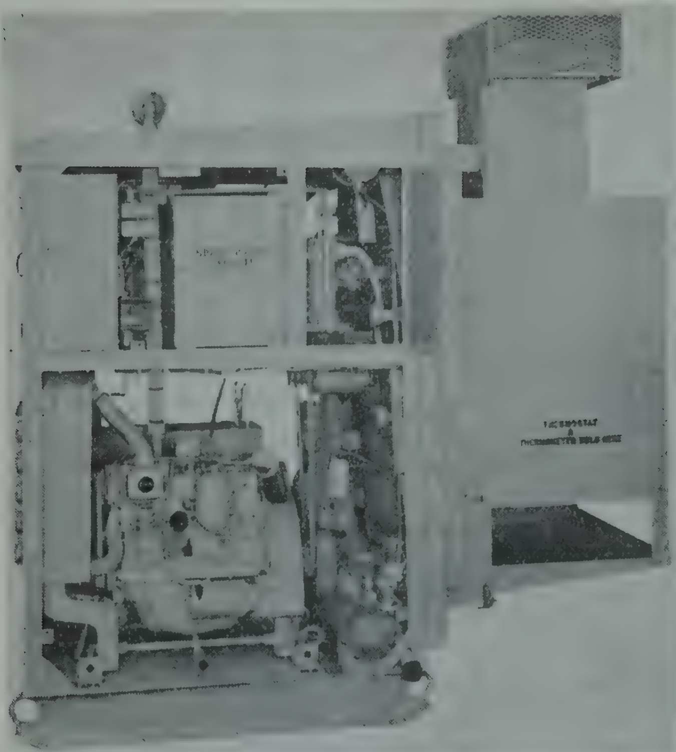


Fig. 4.

frost as often as usage demands by stopping unit (throwing control switch to off, extending suction hose, attached to pump, into a can of water); and operating the pump, permanently connected to defrost header, by hand. This water trickles down the coil surface and passes out of drain (not shown). Complete defrosting is accomplished in about 15 min with a temperature rise in an empty warehouse of from 15 to 25 F. No figures are available for a loaded warehouse, but temperature rise would probably not exceed 7 F.

Fig. 5 applies to the same unit. It shows the heat exchanger and superheater, in reality a two-stage system. By locating the expansion valve control bulb on the suction side of the heat exchanger a fully charged evaporator is obtained, and by means of the superheater an efficient suction temperature approaching 90 F is reached for the gas entering compressor. Notice also spare liquid receiver with capped charging line attached; sight glass in liquid line (bubbles indicate low refrigerant charge); and solenoid valve to prevent liquid surge by keeping refrigerant from passing into evaporator during off cycle.

The evaporator with its distributor system is shown, with a coil 8 rows deep, 16 rows wide, divided into 4 circuits, each fed by a distributor lead and all discharging into a common suction header. Tubing is $\frac{5}{8}$-in. copper, three fins per inch. In this unit, the cranking time limiter, magnetic switch, vacuum switch, and automatic choke were for the first time synchronized to function in a refrigeration system.

The storage battery is located between the gasoline tank and the engine. Also shown are discharge side of compressor, suction and discharge lines with vibration absorbers, generator which also functions as belt tightener for the evaporator blower drive, expansion valve, main and spare liquid receivers and numerous connections.

Fig. 4 is a right side view with panels removed. The engine shown had magneto ignition which was later changed to distributor and coil. Drive is through centrifugal clutch which engages when engine speed reaches approximately 600 rpm. Suction side of compressor shows oil separator and filter, also oil level bull's eye. The engine crank-case oil drain extends through the panel. The exhaust pipe, which extends vertically from the exhaust manifold to the muffler above the roof, is insulated to remove that source of heat from the compartment. A temperature of 850 F has been recorded on this pipe. The hand pump seen in upper right is used for water defrosting of the evaporator coil. The coil may be cleaned of accumulated

Testing Procedure

Lacking means for complete tests, the Engineer Corps required specifications as follows: An added heat load test shall be conducted on the refrigeration unit installed in the structure in accordance with the following procedure: (1) Thermo-

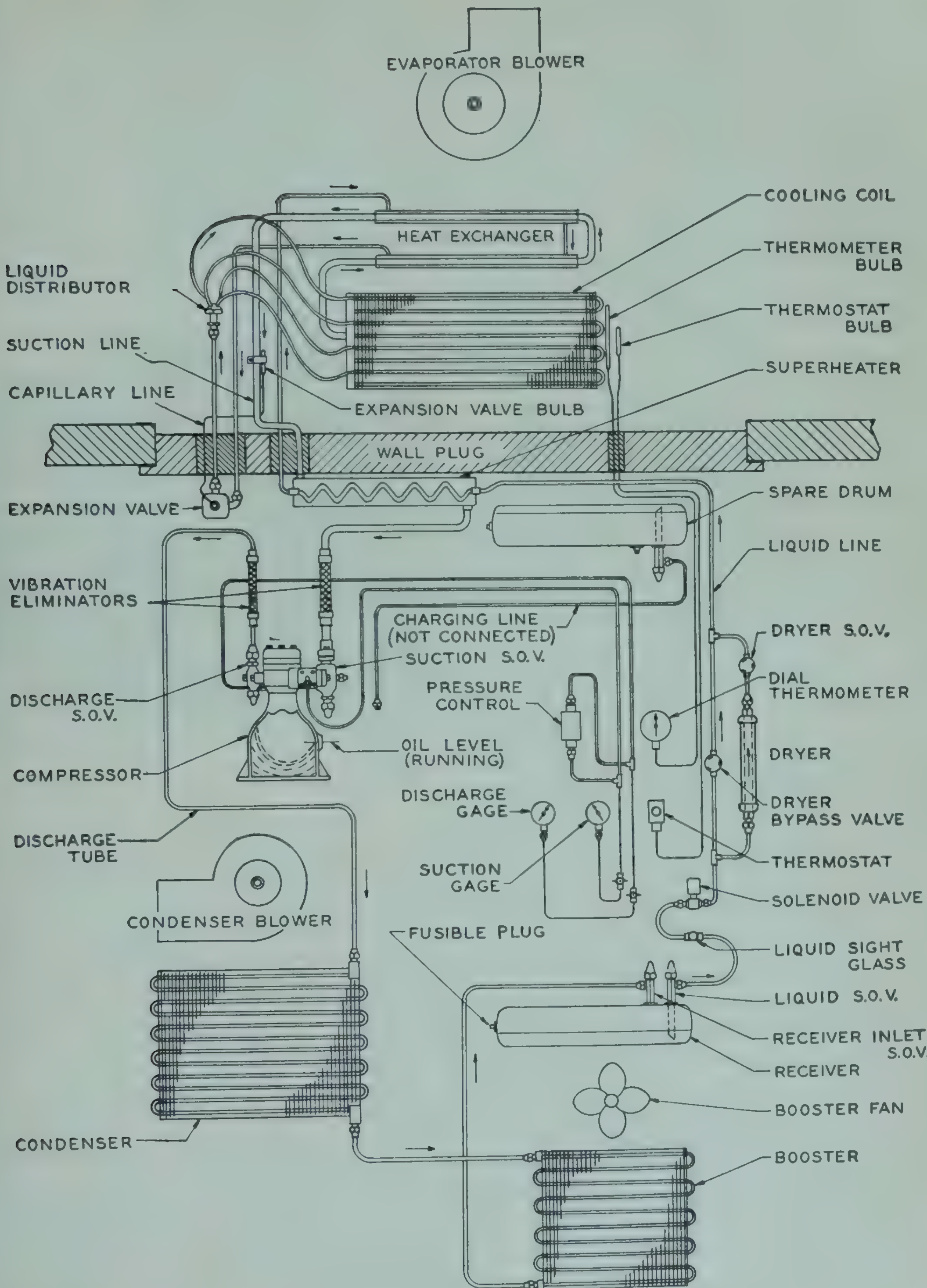


Fig. 5. Refrigeration System Diagram.

couples shall be located in the air streams entering and leaving the evaporator; (2) entrances to structure (warehouse) shall remain sealed throughout test; (3) refrigeration unit shall operate in an ambient temperature of 110 F (plus or minus 2 F); (4) sufficient heat shall be added to interior of structure to maintain a temperature of 10 F (plus or minus 1 F); (5) the temperature of the interior of the structure shall be considered as being the average of the temperatures indicated by four thermocouples properly spaced therein; (6) a recording wattmeter shall be used to indicate the quantity of electrical energy added; (7) recording pressure indicators shall be on suction and discharge lines.

The test is considered concluded when four consecutive hourly readings indicate that temperatures have been maintained within plus or minus 1 F of requirements and the electrical input has not varied in excess of 5 percent. Net refrigeration capacity is considered as the sum of the electrical energy (expressed in Btu per hr) used during added heat test, and the leakage loss (expressed in Btu per hr) as determined by the leakage loss test.

Many structural features which had made the first models unfit for field service were redesigned. For example, steel pipe with threaded joints was replaced by copper tubing with soldered or flare joints (flare up to $\frac{3}{8}$ in.). Magnetos were not available in the quantity required, so the distributor and coil type engine ignition was adopted.

In addition to the prefabricated warehouse, these refrigeration units were also used on the larger warehouses of dimensions 20 ft $\times$ 52 ft, and 20 ft $\times$ 100 ft, requiring three and four units respectively. This plan was not advocated if more adequate compression equipment could be obtained. This same unit was also furnished with electric motor drive and without clutch. These latter units were the exact duplicate of the standard unit except for the motor drive.

Walk-In Refrigerators, 150 cu ft

One of the first refrigeration facilities procured for this war was the portable refrigerator developed by the Bureau of Yards and Docks, U. S. Navy. Its purpose was to furnish a self-contained refrigerator to be shipped, loaded with foodstuffs, for landing as soon as beachead was established. The specifications called for a portable refrigerator to be known as Utility 7, Design 2, Model 0, consisting of two major parts, the cold storage room and the refrigerating unit, enclosed within a common structural steel frame. The complete assembly was mounted on heavy oak skids, equipped with four towing eyes at the bottom corners and four lifting eyes at the top corners (Fig. 6). Over-all dimensions were 8 ft 6 in. long by 6 ft 6 in. high by 6 ft wide. Interior lining was of galvanized, exterior of black sheet steel, with 4-in. insulation. The unit was built for out-of-door use. The refrigeration system had optional drive, by either gasoline engine or electric motor. (See Fig. 7, page 479.)

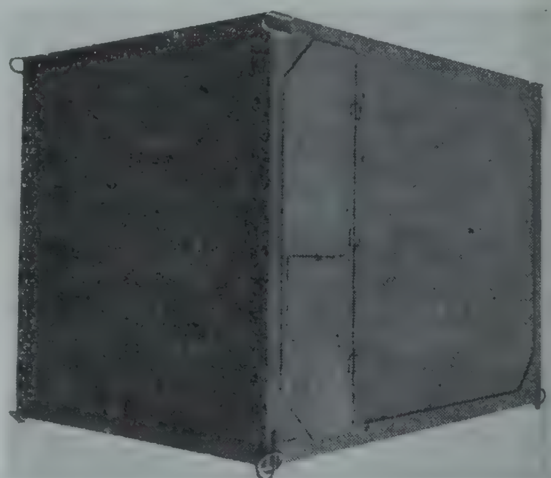


Fig. 6. Army 150-cu ft Portable Refrigerator.

The condensing unit for this refrigerator included four-cylinder, liquid-cooled engine with overriding clutch, driving through a double-end motor, the compressor, con-condenser fan and chamber-evacuating blower. When engine drive was desired, the electric motor acted as a countershaft, but became the prime mover for electric drive as the engine was cut out by the clutch. This changeover was accomplished by throwing a switch. Engine drive was possible in case of motor breakdown.

Control operating on either power source

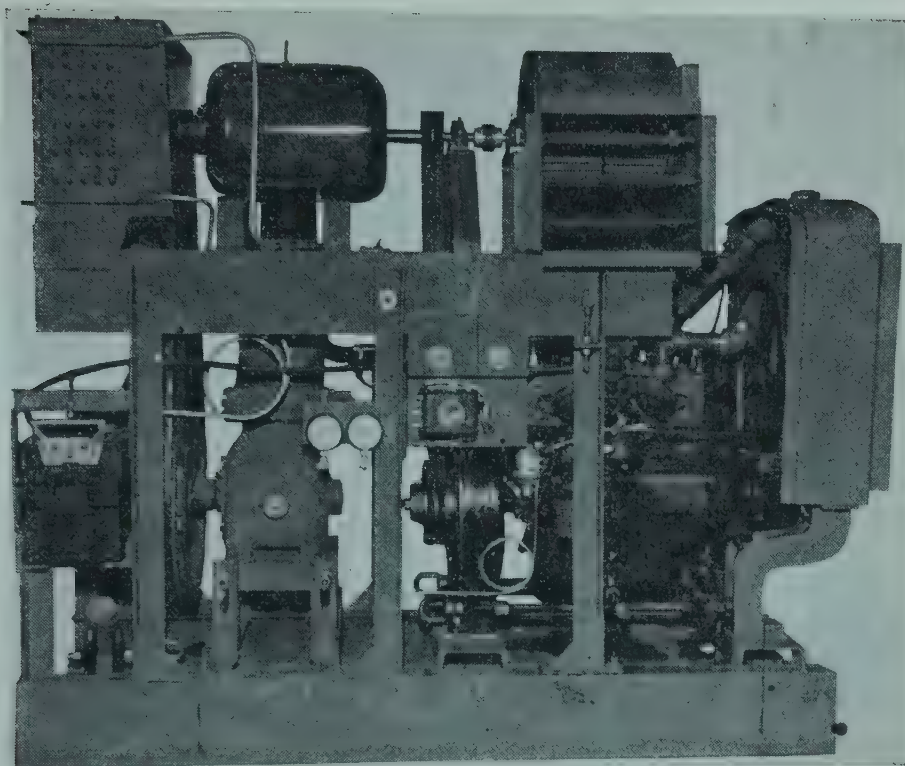


Fig. 7. Refrigerating Unit for 50-cu ft Portable Refrigerator.

was fully automatic. The evaporator consisted of six plate-type coils arranged in three pairs, each pair fed by a thermostatic expansion valve. Refrigerator temperature was controlled by a thermostat adjustable to either 10 F or 35 F.

The Q.M.C. had a similar unit, with a blower coil. In this refrigerator the complete packaged unit was welded, instead of being bolted, to the refrigerator proper. The compressor ($2\frac{1}{2}$-in. bore and 3-in. stroke) was the same as had been used in the prefabricated unit, but operated at reduced speed. For similar reasons, the same controls and other parts were used on refrigerated trailers. Standardization was used where possible, to obtain interchangeability of spare parts. As vibration absorbers were unobtainable, large diameter loops were formed into the suction and discharge lines. One large, insulated heat exchanger was required per unit, located just below the strainer and dehydrator.

Capacity, as determined by ASRE Test Code on Mechanical Condensing Units (Standard 14), was 5000 Btu per hr when operating at a suction saturated vapor temperature of -10 F, a refrigerant vapor temperature of 80 F, and a condenser air entering temperature of 110F.

The dimensions of the cabinet are $76 \times 101 \times 71$ in. It consists of a primary framework of structural steel members assembled by welding, with subframe of wood timbers to which the interior lining and bumper strips are secured. Exterior metal lining of walls and top are of 20-gage, the bottom of 18-gage black steel. Top outside lining is applied outside and overlapping steel frame, to bottom of angles. Outside floor and wall lining are applied inside of steel frame. All joints are sealed with suitable vapor-proof seal.

Portable 25-cu ft and 50-cu ft Refrigerators

The Army Quartermaster was given the task of developing a low temperature refrigerator that could be loaded in the body of a 1-ton trailer which, attached to a jeep, could be hauled over all sorts of terrain. Shipment by air and water are also possible.

Contractors submitted models used to assist in writing final specifications calling

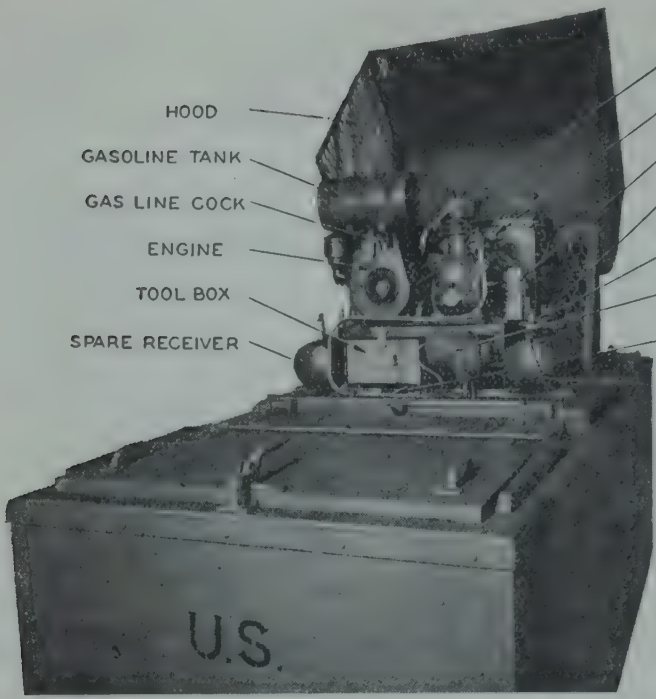


Fig. 8. Refrigeration Unit, Portable—25 cu. ft.

for (1) A cabinet 7 ft 10 in. ×3 ft 2 in. ×2 ft 5-13/16 in. outside; (2) two top doors, hinged, lifting at either end, between which is mounted: (3) a single-cylinder, air-cooled gasoline engine driving a condensing unit having a capacity of 1700 Btu per hr when operating at a suction saturated refrigerant temperature of 10 F, a refrigerant vapor of plus 15 F entering compressor and a condenser air entering temperature of 120 F. The brake horsepower of compressor and condenser fan was limited to 0.9 hp at the above operating conditions.

The cabinet frame and condensing unit housing were constructed of structural steel shapes and wood, covered with sheet steel of 0.0299-in. nominal thickness, with a lining of galvanized or galvanealed steel sheets of 0.0239 in. The insulation was 4 in. of corkboard in two 2-in. layers. Spare receiver contained a full charge of Freon-12, cooling being by a plate type evaporator, with eutectic solution having a freezing point of −2 F and holdover capacity of 6000 Btu or more. The engine ran at 3000 rpm, the ignition automatically shutting off after the eutectic froze (Fig. 8). The compressor, of 1¾-in. bore and 1¾-in. stroke, operated at 895 rpm. Later models used a solution freezing at 25 F.

The 50-cu ft portable refrigerator of the Q.M.C. was designed for knock-down shipment by air. It operated with either electric power or gasoline, both being available in the same unit.

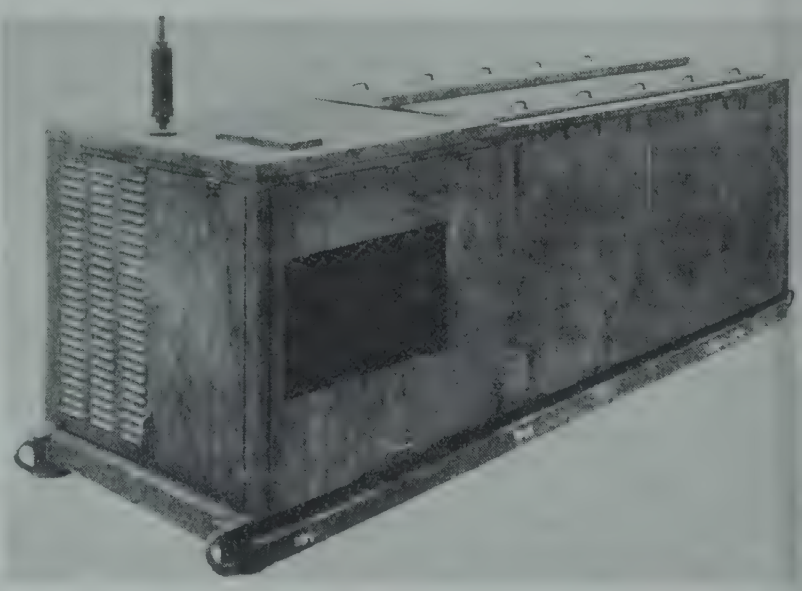


Fig. 9. Ice Plant, One Ton, Portable, Showing Complete Unit.

Portable One-Ton Ice-Maker

Early in the war preparations it became vident that a portable ice-maker would e a necessity. Ice was needed for food and rug preservation, drinking water, mess acilities, first aid stations, and many other equirements. The Engineers Corps deided in favor of can ice. Air agitation was iot necessary, as opaque ice, made from vater either taken from purifiers or proprly treated, would suffice. The size of the lant was determined by the weight capacty of a 2½-ton truck, and by available notorized cranes.

The specifications called for a complete ce-making system (Fig. 9) capable of manifacturing 1800 to 2000 lb of ice in 24 hr, in insulated calcium chloride brine tank ontaining twenty 50-lb ice cans (ice to be iarvested twice daily), insulated covers, an supports, evaporator coils, etc. All were o be mounted on two "I" beams, which hould extend beyond the end of the brine tank to support the gasoline-engine-driven condensing unit, which in turn should be covered with a suitable weather-proof housing. These skids were equipped with lifting eyes.

A four-cylinder liquid-cooled engine was provided for an air-cooled condensing unit, Freon-12, with spare charge in extra receiver. The engine had magneto ignition and manual starting, high- and low-pressure cut-outs, with the latter set to ground the magneto when all the cans were fully frozen. The evaporator consisted of two rectangular 1¼-in. black steel pipe coils, each row encircling one row of 10 cans with sufficient surface to produce the required amount of ice at a brine temperature not less than 8 F, in 20 galvanized steel 16-gage ice cans each 14×5×32 in. The entire ice-making machine was required to manufacture not less than 1800 lb of ice in 24 hr at an ambient of 100 F with water supplied at 90 F.

If you searched this chapter for something which was not found in it, please let the editors know.

42. CARE OF PERISHABLES IN SHIPS' STORES

FEEDING ships' crews and passengers, especially on long voyages, has been a problem for at least five hundred years.

DANIEL C. McCOY, Editor-in-Chief 1950 Applications Volume ASRE Data Books, and Co-author Chapter 42. Born 12/22/94 in New York, N.Y. Educated at Cornell University, Chemical Engrg., 1917. Formerly with U.S. Army Signal Corps and Air Service, 1917–19; Power and Mechanical Dept., Stonega Coke and Coal Co.; Sales Engr., Selas Co.; Salesman, Sales Manager, and General Manager of Automobile Distributorships, 1919–25; Sales Engineer, Zone Manager, Asst. to Commercial Sales Manager, Manager, Product Appln. and Development Dept., Manager, Home Freezer Sales, and General Sales Dept., Frigidaire Division, General Motors Corporation, Dayton, Ohio, 1925 to date.

Edited Commercial Sales Engineering Manuals for Frigidaire 1932, 1935, and 1940 editions; numerous company technical publications; contributor to "Freezing Preservation of Foods" by Tressler and Evers; Author of articles in trade and technical publications; Associate Editor Section IV and Co-author Chapter 39, 1946 Applications Volume, ASRE Data Books.

Member Amer. Soc. of Refrig. Engrs.; speaker at national and section meetings; member of Publications Committee, 1943–45; Chairman, Awards Committee 1948–49; Member, Technical Committee A-7 and Publications Committee, 1949–50; Director, 1949–51; Member, Inst. of Food Technologists; Amer. Soc. of Agric. Engrs. Fellow, Radio Club of America; Member, Engrs; Club of Dayton, Ohio; Reg. Professional Engineer State of Ohio.

Awarded Certificate of Appreciation by Quartermaster Subsistence Research and Development Laboratory, World War II.

At present with the General Sales Dept., Frigidaire Division, General Motors Corporation, Dayton, Ohio.

MARY E. PENNINGTON, Co-author Chapter 42. Educated at University of Pennsylvania and Yale University. Formerly, in charge of Bacteriological Laboratory, Dept. of Health and Charities, Philadelphia, Pa.; Director of Chemistry, Women's Medical College of Pennsylvania, Philadelphia, Pa.; Bacteriological Chemist and Chief of Food Research Laboratory, Bureau of Chemistry, U.S. Dept. of Agriculture; Director, Research and Development, Amer. Intl. Corp.; Consultant to Director, Food Control, War Shipping Administration, World War II; Consultant, Military Planning Division, Office of the Quartermaster General, U.S. Army, World War II.

Co-author, "Food and Food Products," Interscience Publishing Co., New York, N.Y.; "Eggs"; Author, Handbook on "Care of Perishable Food Aboard Ship"; articles in *Refrig. Eng.*, *Jrnl. Amer. Chemical Society*, *U.S. Egg and Poultry Magazine*, *Ice and Refrig.*, *Jrnl. Biological Chemistry*, etc.; Chapter 39, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engs.; ASRE Council, 1945–48; Publns. Committee; Editor, Application Data Sections; Member, Amer. Chem. Society; Inst. of Food Technologists; Poultry Science Assn.; Amer. Soc. for Adv. of Science; Society of Biological Chemists; Inst. of Amer. Poultry Industries.

Awarded Garvan Gold Medal by American Chemical Society.

At present, Consultant, New York, N.Y.

Columbus brought with him cows for their milk and flesh, and chickens to lay eggs and finally to be themselves eaten. But scurvy still took its toll. The death loss in Magellan's crews was so heavy that such long voyage explorations were almost abandoned. Then came the discovery that lime juice would prevent scurvy, and, about two hundred years later, a ration of lime juice for each man was compulsory aboard English ships. Now merchant ships' crews demand a diversified, abundant diet.

Many sailing ships carried ice to preserve their own stock of perishables. Sailing ships long ago carried ice as cargo to the tropics. With the development of steamships and the increase of passenger traffic, ships' stores had to include a full line of perishables.

Shipbuilding in the United States was lagging during the period when refrigeration was developing most rapidly. Great Britain, Denmark and other countries built refrigerated ships in considerable number. The temperatures provided for cargo and ships' stores followed those commonly used in European land based warehouses, in which freezers often rose to 26 F and almost never fell below 14 F.

During World War II, Great Britain not only greatly increased her consumption of fish but used it as a backlog of the protein food supply. Accordingly, a considerable number of warehouses maintained temperatures of 0 F and below in fish storage rooms. Gradually other British refrigerated warehouses are lowering temperatures to the United States levels of 0 F and below, a practice which may be expected to extend to the freezer rooms aboard ships to carry ships' stores as well as to cargo holds.

In the United States the almost universal dependence on low temperatures for the preservation of perishables is becoming apparent to ship operators. Hence, shippers can by shopping around among cargo carriers find ships which will, for example, furnish −10 F for such products as frozen, sugared pineapple or 0 F to −5F for fro-

zen fresh milk; and cooler products, such as apples and pears, can be assured of 32 F. On the other hand, the usual refrigerated cargo ship will not promise temperatures lower than 18 F and for ships' stores we seldom find temperatures lower than 15 F in the freezers and the coolers are more apt to run at 40–45 F than at 32–34 F.

Refrigerated spaces for ships' stores were designed to carry perishables from the originating port to a destination where supplies for the return trip were to be obtained. The peacetime voyages of cargo ships were comparatively short with perhaps intermediate stops at island ports. Now conditions have changed; foodstuffs are scarce and many ports have little for merchant ships. The men of the American Merchant Marine are accustomed to an American diet, fresh beef and lamb, fresh vegetables, eggs in the shell, and ice cream. United States ports alone have sufficient suitable supplies, and here, perforce, most United States ships must provision for the round trip.

For example, United States ships only occasionally purchase fresh fruits and vegetables at Mediterranean ports. The methods of cultivation are not those of North America, especially surface crops, hence such supplies are obtained for the round trip from home sources. In peace time, with normal crews, vessels are not required to provision for more than 90 days except for unusually long voyages, such as to South Africa or India.

The provisioning habits of the ships are governed largely by the routing and the length of the voyage as well as by the amount of refrigerated space and the temperatures available. At ports where good fresh fish can be obtained or fine meats can be had, supplies are put aboard. Nevertheless, United States ships depend for the bulk of their provisions on the United States markets.

Perishable foods go aboard as dehydrated, smoked, salted, cooled, frozen and canned. Dehydrated vegetables such as onions or potatoes and dried eggs must for long voyages or in the tropics be kept below 50 F. Refrigeration is the surest way to prevent insect infestation in cereals. Our cargo ships generally lack sufficient cooled space for packaged food.

Provisioning for the crews of cargo ships is made in accordance with the number of men aboard and the length of the voyage. The men of the Merchant Marine consume more food per capita than those of the Army and Navy. The Navy allows 1985 lb per year per man, while the Merchant Marine allows 2555 lb, or about 7 lb per day.

One may then conclude that ships' stores will be loaded for holding periods beyond the average four months which prevails on land. This sometimes imposes a difficult requirement for a refrigerator of the relatively small size found aboard ship.

Amount and Distribution of Space

On prewar trans-Atlantic voyages ships were provisioned at the port of embarkation. The trip was not too long for the old idea of low temperature, 20 to 26 F for freezers. Merchantmen had two or three small rooms—one for frozen foods and one for fresh fruits and vegetables. This might provide on the order of 500 to 800 cu ft. In the North Atlantic, the freezer temperature could generally be kept below 20 F. In tropical waters it might easily go to 26 F and sometimes higher. Results were less satisfactory for ships plying between North American ports and South Africa or making other long voyages.

With two refrigerated rooms, say $8 \times 10 \times 7$ ft or $8 \times 15 \times 7$ ft, careful segregation of commodities is impossible. Into the cooler go shell eggs, lemons, onions, apples, cheese, and smoked meat. In the freezer are found frozen meat, butter, poultry, varieties of bacon, hams, and fish. Before the war, beef came aboard as loins, forequarters, or other large cuts; lamb and mutton in carcass form. The ships received cooler meat and froze what was needed for future use. The temperature of the freezer, seldom below 15 F, gave a relatively slow freezing, with showings of desiccation almost immediately. Now, to save space and waste, ships are turning more and more to fabricated meats, well packaged and hard frozen. Poultry and butter are now generally received hard frozen. Fish may be purchased frozen, frequently as fillets.

Construction

The practice is to mount cooling coils on

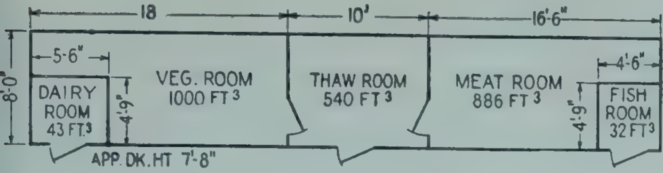


Fig. 1. Floor Plan for Ships' Stores on C-2 Vessels.

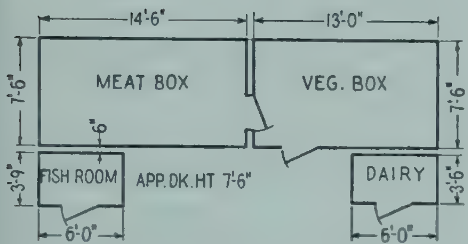


Fig. 2. Ships' Stores on EC-2 Vessels.

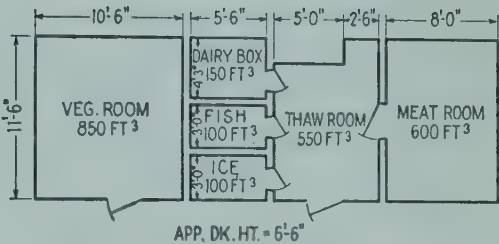


Fig. 3. Ships' Stores on C-1 Vessels.

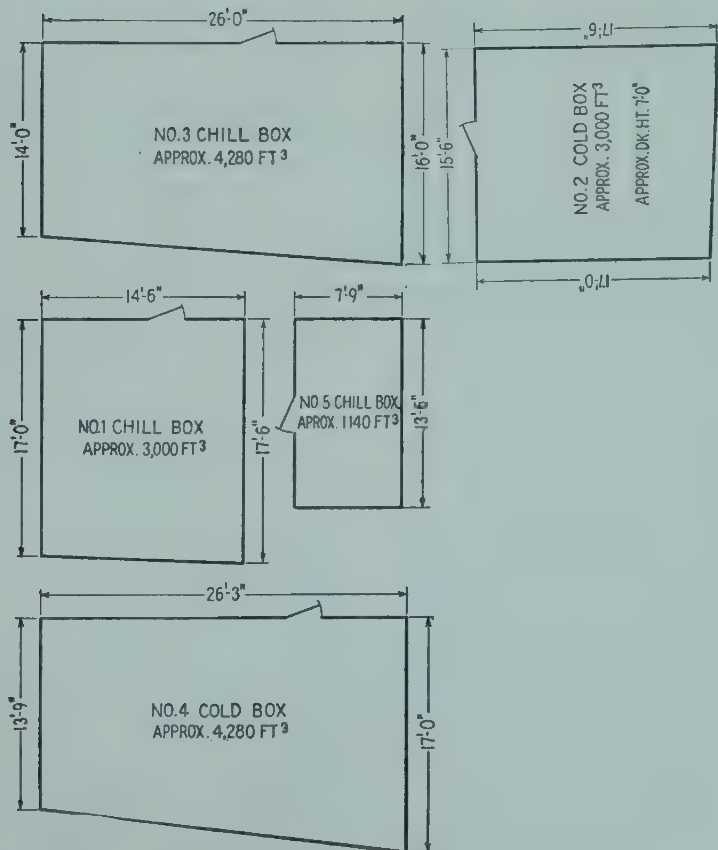


Fig. 4. Ships' Stores on C-3 Vessels

Table 1. Service Compartments—Cargo Ships[1]

Space	Gross volume, cu ft	Temp, °F
Meat	800	22–26
Vegetables	900	35–40
Dairy products	100	45–50
Fish products	100	20
Thaw room	250	45–50

the walls of the box. Cooling is by direct expansion or by cold brine. In some boats bunker coils with fans are used. More recently **unit coolers,** sometimes supplemented by wall coils, have been installed, but difficulties are reported by stewards because of rapid wilting of vegetables in the coolers and undesirable dehydration in the freezers, resulting in freezer burn and reduced palatability.

There is much variation in the size of the refrigerated rooms on different cargo ships. Some ships, especially those with home ports far north, have space scarcely larger than a retail butcher's box. On the other hand, American ships may have three fair walk-in refrigerators with small compartments for special items such as fish or dairy products.

In 1936 the Maritime Commission started its shipbuilding program. The "C" cargo boats, and ships for cargo and passengers got underway. Gradually the different classes of maritime ships crystallized and established fairly uniform facilities for the conservation of ships' stores.

Refrigerated space. Figs. 1 to 4 are typical layouts, with average dimensions of the refrigerated rooms for ships' stores in four types of United States cargo vessels. Details vary according to the ideas of different designers and builders. Rohn and Clarke[1] give gross volumes in service compartments of cargo ships, and passenger and cargo ships, as in **Tables** 1 and 2.

C-1, C-2, and EC-2, which is better known as the Liberty, are typical cargo ships. Their refrigerated space runs from 1961 cu ft in the C-2 class to 2350 in the C-1. The Victory ships, with a speed of 15 knots or over and with comfortable quarters for crews, have 3986 cu ft of refrigerated space. The C-3 class, with a speed of 16½ knots, are handsome ships and may readily be converted into passenger carriers. Accordingly, they are equipped with two freezers aggregating 7280 cu ft, and three coolers aggregating 8420 cu ft, or a total of 15,700 cu ft. The rooms are arranged around three sides of a hatch, into which the doors open.

Not all the space enclosed by insulated walls, or artificially cooled, is available for actual stowage. What with space out for pipe coils, vertical battens, floor racks, lighting fixtures and construction details, 25 percent or more cannot be used. The smaller the room the greater the space lost. For example, a little box intended for fish has a gross space of 153 cu ft, but only 93 cu ft are usable, making a loss of 39 percent. A box for vegetables containing a total of 645 cu ft loses 18 per cent, leaving 529 cu ft to be used. When, therefore, the actual space for commodities is to be determined, about 25 percent must be deducted from the cubical dimensions as given in Tables 1 and 2 and from Figs. 1 to 4. The Liberty ships, with 2022 cu ft gross, then fall to 1517 cu ft, and the Victory ships having 3986 cu ft gross may be expected to net about 3000 cu ft.

Supplies. It has been stated that approximately 2555 lb of food is allowed per man per year by the Merchant Marine. Of this total we may expect perishables to be on the order of 1000 to 2000 lb, depending upon the time of year the ship is provisioned.

The varieties and quantities as given in Table 4 represent a typical midsummer

Table 2. Ships' Service Compartments—Passenger and Cargo Ships[1]

Space	Gross volume, cu ft	Temp, °F
Meat	735	15–20
Poultry	220	15–20
Fish	220	15–20
Thaw room	320	40–45
Butcher shop	280	35–40
Ice and ice cream	225	20–25
Milk	240	40–45
Milk preparation	125	40–45
Vegetables	1075	40–45
Butter and eggs	365	40–45
Fruit	260	35–40

Table 3. Comparison of Temperatures in Service Compartment of Cargo and Cargo-Passenger Ships with Standard American Temperatures for Food Preservation

Products	Cargo ship temp, °F (Table 1)	Passenger and cargo ships temp, °F (Table 2)	Standard practice, °F	Keeping time and quality when held at			
				40F and above	15 F	10 F	0 F and below
Meat	22 to 26	15 to 20	0 and below		Pork rancid in 2 months. Beef, lamb, veal—3 months	Pork rancid in 4 months. Beef, lamb, veal—5 months	Good flavor at end of year—all meats
Poultry		15 to 20	0 and below		Chicken rancid 3 months	Chicken rancid 5 months	Good for 12 months and over
Fish	20	15 to 20	0 to −20		Lose quality faster than at 10F	Rancid or bad flavor 2 to 3 months	Non-fat fish 0 to −20 F 1 yr. Fatty fish—salmon, mackerel 6 months
Ice		20 to 25	28				
Ice cream[6]		20 to 25	−10 and −20				At −6 F good for 6 months, except vanilla and strawberry
Milk		40 to 45	30 to 32	Cannot be depended on for more than 72 hr.	Frozen heavy cream keeps well at zero or below for average of 3 to 9 months. Must be specially treated after thawing. Whole milk requires special preparation before freezing.		
Vegetables	35 to 40	40 to 45	Fresh, 32 to 45. Frozen, zero or below		Lose quality faster than at 10F	Lose quality in 3 to 4 months	Good for 12 months or more
Butter	45 to 50	40 to 45	0 to −20	Off flavor in 4 to 6 weeks or less	Frozen butter should be held at zero or below		At −5 to −20 F. Keeps more than one year.
Eggs: Shell Frozen Dried	45 to 50	40 to 45	29 to 31	Not dependable after 4 weeks at 40 and above. Must be stored at zero or below. Stored below 50F.			
Fruit		35 to 40	Fresh, 32 to 45. Frozen, zero or below	Some not more than a few days	Lose quality faster than at 10°	Lose quality in 3 to 4 months	Good for 12 months or more

Above data taken from Government bulletins, The American Society of Refrigerating Engineers Data Books, bulletins of State Experiment Stations and (unpublished) reports of Association of Refrigerated Warehouses.

list. In winter, when fresh fruits and vegetables are not in such abundance, the quantities are less and canned goods take their place. We may expect then to provide from 80 to 170 lb per month per man of fruits, vegetables, meats, butter, eggs and like commodities. When, as in the late summer or autumn, long keeping potatoes can be obtained, 5000 bushels or more are frequently provided. Forty bags of potatoes are commonly allotted to 100 cu ft. Therefore, if the voyage is long and the vegetable room of the ordinary size, potatoes for the outbound trip are stored in bins outside of refrigeration and only those bags needed for the return trip are refrigerated. The same may be said of cabbage.

The Navy allots 4 to 5 cu ft of refrigerated space per man per month. On this basis the Liberty ships, with a net of 1517 cu ft, can provide for 75 men for a 4 months' voyage and for 50 men for 6 months, while the Victory ships, having a net of about 3000 cu ft, can take care of 100 men for 6 months.

Temperatures. In Table 3 there is presented a summary of the temperatures scheduled for refrigerated rooms for ships' stores as well as the temperatures generally accepted by the refrigeration industry. The

effects of time in storage are given also for certain products at a range of temperatures from 0 to 15 F,[2,3,4] as well as what may be expected to happen in coolers maintained at 40 F (where 32 F is prescribed).[5] Table 5 gives temperatures and allocations of space as specified by the Maritime Commission.

It was never supposed by the original ship designers that such commodities as pork cuts, poultry and fish should be held at 20 to 26 F for more than a few weeks. There has been a resulting loss of the food, and perhaps a serious loss of palatability and failure of meals to be consumed. No restaurateur wishing a satisfied clientele dares to serve chicken desiccated and of off-flavor, or eggs which taste of lemons, celery, and onions.

Toward the close of the war and based on experience—some of it rather bitter, War Shipping issued the following order:

"Superseding and replacing all previous instructions with reference to refrigeration temperatures, the following temperatures shall be maintained in all boxes:

Egg and cheese box (formerly dairy box): 30 to 31 F; never below 30°.
Vegetable box: 32 to 34 F.
Meat box: The temperature shall be set as low as possible. (0 F is recommended.) Under no circumstances shall the temperature be held above 10 F.
Fish box: The temperature shall be held as

Table 4. Ships' Stores—Perishables—Cargo Ship Supplies for 3000 Meals
(Purchased in midsummer)

Classes of foods	Commodities	Quantity, lb	Total, lb
Fresh fruits	Apples, table, 138s	88	
	Bananas, half green	15	
	Grapefruit, 80s	120	
	Lemons, 360s	19	
	Oranges, 176s	135	
	Pears, box	11	388
Green vegetables	Beets	20	
	Cabbage	50	
	Carrots	50	
	Celery	132	
	Cucumbers	24	
	Eggplant	30	
	Garlic	10	
	Kale	36	
	Lettuce, iceberg	120	
	Onions, yellow	50	
	Parsley	3	
	Peppers	18	
	Radishes	6	
	Spinach	60	
	Squash	100	
	Tomatoes	150	
	Turnips, yellow	25	884
Potatoes	Potatoes, sweet	200	
	Potatoes, white U. S. #1	750	950
Butter	Butter, prints, 92 score	130	130
Eggs	Eggs, U. S. std. fresh	150 doz	5 cs
Milk	Milk, fresh	510	510
	Ice cream	105	105
	Cheese	40	40

Classes of foods	Commodities	Quantity, lb	Total, lb
Meat	Beef, boneless rounds	116	
	Striploins	37	
	Tenderloins	16	
	Ribs	48	
	Sirloins	37	
	Chuck	142	
	Plates	48	
	Brisket	26	
	Hamburger	58	528
	Kidneys	5	
	Liver	25	
	Tails	25	
	Tripe	3	58
	Veal, boneless	90	
	Veal, whole, boneless	65	155
	Pork, loins	100	
	Hams	100	
	Spareribs	14	
	Bacon, sides	85	
	Smoked hams	115	
	Tongue	15	
	Corned pork bellies	15	444
	Sausages and head cheese	115	
	Corned beef	39	154
Poultry	Chicken, choice	57	
	Ducks	43	
	Fowl. choice	86	
	Turkey, choice	29	215

low as possible. (0 F is recommended.) Under no circumstances shall the temperature be held above 10F."

Rohn and Clarke[1] have described the mechanical equipment put on some of the earlier Merchant Marine craft for ships' stores, including the use of continuous lengths of bent galvanized steel pipe coils at the familiar ratio of 1 sq ft of cooling surface per 6 cu ft of gross room volume. Evaporation temperatures of 0° and 15 F were specified for freezer and chilling rooms. Unit coolers have been used in the vegetable and fruit compartment. Ice making units, ice cream freezers, and drinking water coolers are commonly provided on ships.

Packaging and piling. When the ship has only its normal complement of men or when the voyage is for not more than 90 days, the various kinds of perishable foods to be carried in the refrigerators may be segregated and piled warehouse fashion, permitting ready access to each sort of commodity. When, however, the refrigerated space must be solidly packed, the packages should be sorted on the dock and each pallet load should contain beef, lamb, pork, and veal in the proportion each bears to the entire supply. The freezer is then stowed from the back of the room forward, so that each kind of meat is readily accessible.

The manner in which perishables are stowed aboard ship is even more important than the piling in a land-based warehouse. Vertical stacks must be firmly based and should be as nearly as possible of the same height. Vertical battens are resorted to when necessary. Piling athwart ship rather than fore and aft is also helpful. When coils are mounted on the walls vertical battens 2 to 4 in. in front of the pipes will prevent the packages from resting against the pipes and ensure air circulation around them. Sufficient space must be left beneath the ceiling to permit air movement. Small packages must not be tucked between the ceiling and the meat rails in the freezer. Carcasses must be hung from the rails, and hams, bacon slabs, sausages either hung from hooks or properly stacked on the wire shelves with which the freezer is commonly provided. The more delicate commodities should be stowed away from the door where warm air does not so readily penetrate. Kegs or buckets containing corned meats must be placed on the floor where leaking brine can be most easily cleaned up. Butter is better in prints packed in fibre cartons than in tubs; also lard, if obtainable. Butter should be placed in the freezer and lard, also, if there is space enough, though it will carry well in the cooler.

Table 5. Disposition of Perishables among Various Refrigerated Rooms and Temperatures Specified by the War Shipping Administration

Meat Box—0 F to 10 F Preferably 0 F
Beef, pork, veal, lamb, etc.
Corned meats and cold cuts
Ham and bacon
All sausages
Poultry
Butter and yeast
Ice cream
Frozen foods
Non-sterile canned meats
Bought bread for long holding.
Vegetable Cooler—32 F to 34 F
Fresh fruit and vegetables
Root vegetables—potatoes, carrots, etc.
Dehydrated eggs, lard
Dehydrated onions and cabbage
Bought bread (well-packaged)—for short holding
Dried fruits, leftovers
Strong cheeses.
Dry Storeroom
Canned and bottled foods
Coffee, flour
Cereal products
Salt, sugar
Dried beans, peas, rice, etc.
Evaporated, dried skim and dried whole milk.
Fish Box—0 F to 10 F Preferably 0 F
Frozen filleted fish
Frozen fish in round
Smoked and salt fish
Fresh fish.
Egg and Cheese Box—30 F
Shell eggs
Fresh milk
Packaged mild cheese.

Until fresh meat for the Army was boned and packed in fibre cartons, 15 × 20 × 5 in. inside measurements, and weighing from 50 to 55 lb, carcass meat was used for ships' stores. Lambs went aboard whole, beef usually in maincuts such as loins and

ribs. Generally it was frozen aboard ship. The boneless meat is frozen by the packer and it is up to the inspector at the ship side to see that thawing has not taken place. While the meat carton is supposed to occupy about 1 cu ft of space, it frequently is so freezer-bulged that piling is difficult. One ton of carcass beef, whether hung or piled, requires 135 cu ft of space. One ton of boneless beef in cartons occupies 36 cu ft of space.

Printed **butter** packed in cartons has taken the place of the tub. Some cartons come aboard fresh, for immediate use; the remainder now is hard frozen. What is left after a long voyage may be used for cooking on the next voyage, provided it is not too rancid and not too moldy. Butter draws the lowest temperature of which the commercial warehouse is capable, preferably below 0 F.

Poultry boxes vary in size according to the size of the birds. As a rule poultry comes aboard box-packed and hard-frozen. Ice packed poultry in barrels will keep only a few days. Poultry boxes are fitted into such spaces as may be available in the freezer. Eviscerated, quick frozen poultry takes about half the space of poultry in the round but it demands a temperature of 0 F if it is to be kept for more than a few weeks.

The **vegetable** room in a cargo ship provisioned to sail is a triumph of packing. Every inch is used and the different commodities must be so piled that each kind can be reached without too much shifting of packages. It would help greatly if vegetables which can be quick frozen, such as peas, beans and spinach, were so carried. A crate of spinach is commonly $13 \times 18 \times 21$ in. and weighs about 41 lb. It occupies 2.8 cu ft. Forty pounds of frozen spinach occupies 1.11 cu ft—a clear saving of 1.7 cu ft or approximately 60 percent. Frozen peas and beans would be equally saving of refrigerator space. The difficulty here is that quick frozen vegetables do not keep well unless held at 0 F or below.

The more perishable **fruits,** such as cantaloupes and watermelons, are stowed near the front of the room and used in the early days of the voyage. Among vegetables, asparagus and broccoli are typical of those to be stowed at the front and used promptly. Apples, oranges, cabbage and white potatoes are typical of fruits and vegetables which are good keepers and may be stowed further back.

Strong **cheeses, dehydrated onions,** and **dehydrated eggs** now are held in the cooler at a temperature of 32 to 34 F.

In the last analysis, the successful utilization of fruits and vegetables depends upon frequent inspection and sorting. When decay is proceeding too rapidly the commodity should be used as fast as possible. If rotten specimens are found only here and there in the package, they should be removed and the remainder watched carefully for further developments.

The purchasing of these commodities must be done with an eye to the season as well as the length of the voyage. Winter apples put aboard in the autumn will normally hold for several months. Not so, when purchased in the spring, near the end of their storage life.

Generally space other than in the refrigerated vegetable room is found for **white potatoes, sweet potatoes and onions.** Sweet potatoes should not be refrigerated. In the late spring when the old potatoes have reached the end of their keeping time, even a three months' voyage is too long. Canned potatoes are resorted to and more recently dehydrated potatoes. If a cool place, not over 50 F, could be found for them, a good

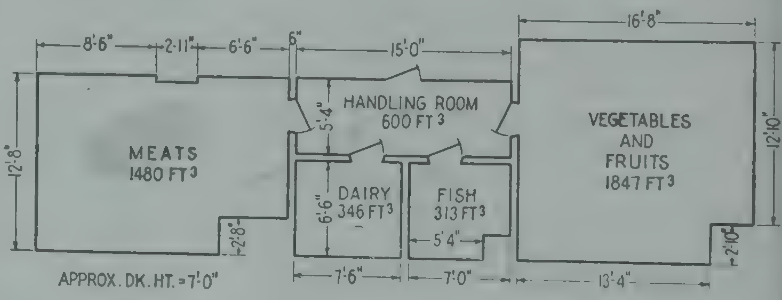


Fig. 5. Floor Plan for Ships' Stores on Victory Ships.

pack of dehydrated white or sweet potatoes should be of service. The same may be said of dehydrated carrots and cabbage, but they must be kept cool and dry.

Before reaching port at the end of a voyage every package of **unused goods** should be stamped or tagged and dated. These packages should then be brought to the front of the room and stacked at the front when reprovisioning so they may be used immediately. Overlooked boxes stuck away in corners where they may remain for several trips are either of poor quality or often inedible.

Supplementary Refrigerated Boxes

The lack of adequate refrigerated space to hold the quantities of perishable products required for the long voyages now demanded of our merchantmen, and the inadequacy of the temperatures furnished to maintain the quality of the stores as purchased, have led to supplementary boxes, self-contained and portable. Different power equipments have been used on these, but the latest models have an air-cooled condensing unit operated by an electric motor from the ship's current. Some are also equipped with an auxiliary gasoline or Diesel engine to maintain refrigeration should operation be required when electric power is not available. See Chapter 41.

The boxes are steel construction with insulated walls, with coils or plates on three interior walls (**Figs. 6 and 7**). A wood rack on the floor and a thermo-regulator are included, and refrigeration equipment is able to maintain a temperature of 0 F. A dial thermometer built into the outer wall of the box enables the engineer to know at all times whether the temperature is being maintained. The refrigerant is Freon-12. The early boxes were 150 cu ft net. Gradually, the size has been increased until now there are many in service measuring 12 ft 9 in.×8 ft×6 ft 6 in. over-all outside, and giving a space over 300 cu ft in the clear inside. A box of these dimensions weighs approximately 7500 lb when empty. Even larger boxes are in the making. Handling is by ship's gear and the lifting eyes, one on each corner of the box. They are commonly placed between decks to protect them from salt spray. There must be plenty of space around them for air circulation.

The aim of the ship's steward is to fill these boxes with supplies to be used on the return trip. Of course, he will select those which require low temperatures for long keeping, such as frozen vegetables, frozen eggs, frozen fish fillets, eviscerated poultry and pork cuts. On the outbound trip, the box is not disturbed unless an accident happens to its refrigerating system. On the return trip, the box is opened and supplies removed, preferably not more frequently than every two days. These supplies are transferred to the ship's thaw room or freezer until required in the cook's galley. Such supplementary refrigerated space, up to 1000 cu ft, has been used for very long voyages, as to India, especially when personnel as well as cargo is to be carried both ways. With the drive now getting under way for the prevention of spoilage and waste of foodstuffs, it is likely that the use of these boxes will be more widespread.

Galley and Service Refrigeration

In addition to requirements for quantity and long-time storage of perishable foods, some refrigerated space must be provided in the galley for service use of the cook or cooks. On cargo vessels, a large **household refrigerator,** suitably altered for marine application requirements, may suffice. When more space is required, a commercial **reach-in refrigerator** (see Chapter 37) of 20 cu ft or more capacity can be used.

On passenger vessels, more space will be necessary, the amount being governed by the number to be fed, the type of clientele, and the variety of the menu. The galley and pantry service refrigeration requirements for passenger-carrying ships will be similar to those of restaurants ashore (see Chapter 40). Service equipment similar to that used ashore can be used, with alterations dictated by marine application conditions. One or more refrigerators should be placed in the galley for the cooks. They would facilitate the utilization of leftovers which now are too likely to go overside. One or more **pantry refrigerators** may also be required to expedite table service. Large

Fig. 6. 150-cu ft Navy Portable Refrigerator.

household refrigerators or commercial reach-in refrigerators may be provided for this work.

A small **ice-cream cabinet** may also be required in the pantry. Ice cream is too hard for convenient service when carried at temperatures given in Table 3 for long-time storage, and it will not keep for long periods at serving temperatures. Serving temperatures vary from +5 to +10 F, depending on the characteristics of the ice cream used, and the method of service. On the larger passenger vessels, such extra features as ice-cream making, bar and soda fountain service may be provided. Refrigeration equipment used for such applications will be similar to that used ashore. Modifications may be required for adaptation to marine conditions, but these are usually of a minor nature if all the general considerations for marine service discussed later in this chapter are provided for.

Bases of Marine Designs

The first subject which must be considered when applying refrigeration equipment to marine service is the **area** in which the vessel will operate. The insulation to be used on the refrigerated spaces, the condensing units, and the cooling units must be selected with this in mind. For example, vessels intended exclusively for North Atlantic service, will require smaller equipment than those which must operate in tropical waters. Atmospheric temperatures as high as 160 to 170 F in the sun with 130 to 135 F in the shade, have been reported from some tropical areas. It is obvious that refrigeration equipment applied for conditions existing in the waters adjacent to the British Isles will be woefully lacking in such tropical areas.

Refrigerated spaces located on decks, against the sides of vessels, or below decks, where their exterior surfaces will be subject to the direct rays of the sun, require special consideration to offset the sun effect when calculating the heat leak. Structural members imbedded in the insulation on marine applications often materially increase heat leakage over that which would apply were the same type of insulation to be applied on a shore installation.[8] Any equipment applied to spaces where warm products or food are to be cooled, such as loads of cased beverages which have been standing on wharves in tropical climates, or where food brought aboard is to be frozen after being loaded into the refrigerated space, requires careful consideration. This refrigeration load must be added to the heat leakage and service loads, and adequate condensing unit and cooling unit capacity must be provided to offset these **product loads.**

The use of safe **refrigerants,** such as those of the Freon group, is highly advisable on marine installations.

The application of **condensing units** to marine installations requires some special considerations. When using water-cooled units, standard condensers usable ashore are rarely suitable for marine installation. On board sea-going vessels, such condensers are supplied with salt water. Harbor waters are often highly corrosive, even inland fresh waters. The standard condensers will very quickly corrode, and it will be only a short time before the water gets into the refrigerant system. Therefore, special metals are required in marine condensers (see Chapter 23). Oftentimes, the location of condensing units used for refrigeration of ship's foods, particularly galley and service refrigerators, present a plumbing problem in handling the condensing water. This may make it advisable to use air-cooled units.

When applying air-cooled units, these must be assured an ample supply of the coolest possible condensing air, and the hot air leaving the condenser must be expelled from small rooms where condensing units are located. Ventilating fans may be required for this purpose. The installation of air-cooled condensing units in confined spaces such as small bar rooms, small ships' galleys, etc., should be carefully scrutinized, to be sure that ample condensing air of the proper temperature is available, and hot air expelled, particularly with respect to galley and service refrigerators.

The maximum condensing medium temperature which will be encountered where the ship is to be used must be considered. Ships used exclusively in North Atlantic service can be equipped with condensing units which will develop required capacity with much lower condensing air temperatures or condensing water temperatures than those vessels which ply in tropical waters. If refrigeration systems are normally used for North Atlantic service, but might be used in tropical service from time to time, obviously the equipment must be applied on the basis of tropical conditions.

It is often necessary to install condensing units in boiler rooms or in engine rooms. When using air-cooled units, the maximum air temperatures in such spaces must be carefully considered. Be sure that electric motors will stand the load imposed and that the condensing units will develop adequate capacity under actual operating conditions.

Unit installations are preferred by many engineers. Today this is good practice ashore and should be adopted at sea. Assuming a series of four refrigerators for ship's food—one for dairy products, one for fruits and vegetables, one for meats, and the fourth for frozen foods—each should have its condensing unit. This provides maximum protection of the perishables in case of mechanical failure of condensing units or other parts of the system. It simplifies control, eliminates "gadgets" required with one large condensing unit and reduces maintenance problems at sea.[9] Foods from one fixture may be moved into one of the others, or by cross-connection, the system may be worked out so that the condensing units still in operation could be switched to the part of the system that has failed. Close temperature control can be maintained with the unit type of system, which is highly important in the protection of perishable foods for long periods of storage. A spare "standby" condensing unit is worthy of consideration.

For cooler storage temperatures (34 F and above), either gravity or forced-air circulation **evaporators** of the finned type are now usually considered in preference to the pipe coils. Finned evaporators of the proper capacity will defrost automatically when operated at cooler temperatures of 34 F or higher. Choice of the correct operating refrigerant temperature, along with automatic defrosting, can result in better moisture conditions in the cooler, with less wilting of fresh vegetables, and less drying out of fresh meats. The reduction of storage life of perishables due to slightly increased holding temperature from the "ideal 32 F" will be small and may be totally offset by the better moisture conditions created if application is properly made.

For freezer storage (32 F or below), the **plate type** of evaporator or pipe coils may be used. However, pipe coils present three major objectionable features, namely, a large refrigerant charge, excessive weight, and defrosting problems. Finned coils **with suitable means for positive defrosting** may also be used.

On smaller vessels, electricity may not be available for 24 hr of the day. In such cases, the "holdover" or "eutectic" plate type of evaporator may be used for both cooler and freezer applications. Gasoline or Diesel engine drive for the refrigeration compressors may be provided in connection with this type of evaporator.

For marine applications, liquid refrigerant **controls** should be of the expansion valve type, especially on small vessels. The rolling and pitching of vessels makes it difficult for float valve type controls to operate correctly. Expansion valves, being spring-operated, are not affected by this condition. Where it is absolutely necessary to use float controls, these should be

mounted so that the vertical plane of operation of the float is fore and aft, rather than abeam of the vessel. Certain types of vessels, namely, those with their propulsion machinery concentrated at the stern, when operating light, ride with the stern lower in the water than the bow. This condition makes float control inadvisable.

Thermostats, low pressure controls and high pressure controls should be of such design that the vibration of the vessel, or the motion of the vessel, when rolling or pitching, will not affect their operation.

The ship's supplies should always include an extra drum of refrigerant, more than sufficient to charge the largest system on the ship. This is especially true if the vessel is in service to foreign ports. Vessels in service between ports in the U. S. can usually get supplies of refrigerant immediately at any port of call. Breaking of refrigerant lines on vessels is encountered more often than ashore, due to vibration and to stresses and strains which are encountered during rough weather.

Manufacturer of the system should be consulted regarding spare parts which should be carried. Several spare expansion valves should always be on hand. Special tools required for servicing the system should be included, as well as service manuals covering operation and servicing. A set of operating instructions for the individual installation should be a part of every marine installation. The manufacturers' representatives should instruct the ship's operating personnel regarding the individual characteristics of the equipment installed, including servicing peculiarities, control adjustments and the operating conditions for which the system was designed. These special instructions should also be provided in written form.

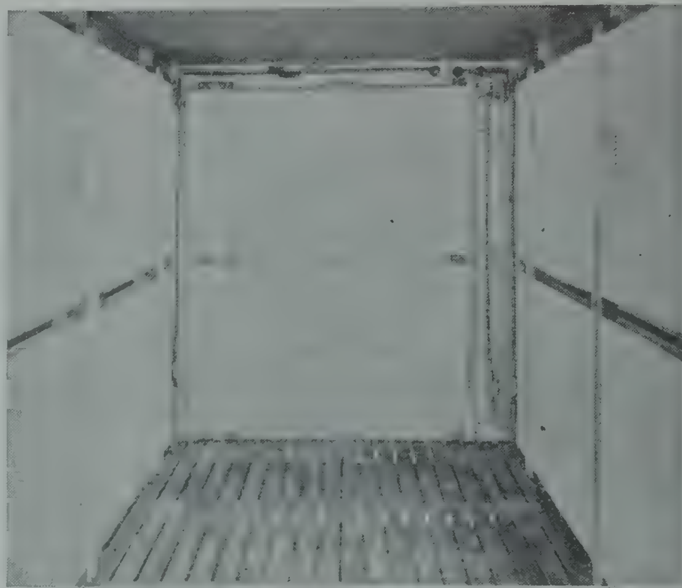


Fig. 7. Interior of 150-cu ft Navy Portable Refrigerator.

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43. DRY ICE IN FOOD DISTRIBUTION

DRY ice finds its largest application as a refrigerant in the transportation of food. Because of its low temperature it is an ideal refrigerant for frozen foods, and its use in the movement of fresh meats, fruits, and vegetables is increasing. It has the desirable property of sublimating directly from a solid to a gas without a residue.

(For manufacture of dry ice see Chap. 53.)

Table 1. Refrigeration Effect from Dry Ice (For complete properties see Chap. 26 Basic Volume, 1949)

Temperature, F	Btu per lb
−30	261
−20	263
−10	265
0	267
+10	268
20	271
32	274
40	275

Temperature at atmospheric pressure, −109.6 F
Specific heat of CO_2 gas, 0.184.
A 10-in. cube weighs 50 to 55 lb

Dry ice has a latent heat of vaporization of 246 Btu per lb at atmospheric pressure. To this value may be added the sensible heat of the CO_2 gas given off. **Table 1** gives latent heat of sublimation of ice, plus the sensible refrigeration obtained as the gas warms to the temperatures shown. In practical applications it is difficult, if not almost impossible, to calculate how much of the sensible heat of the gas is recovered, or how much gas may escape before any of the sensible heat is used. To correct for this loss it is the usual practice to estimate the **refrigeration available** from dry ice as 270 Btu per lb for temperatures above 15 F, and 250 Btu per lb for lower temperatures. These values work out satisfactorily in actual applications of dry ice.

When dry ice is used as a refrigerant in the shipment of fresh foods, it has the two-fold effect of providing refrigeration and giving off carbon dioxide gas. The carbon dioxide gas in the atmosphere immediately surrounding the product serves as a means of reducing the oxygen content of the air and reducing possible deterioration due to oxidation. Also, it inhibits the growth and development of bacteria and various molds which cause spoilage, and it may slow down enzymatic action within the product itself.

Shipment of Meats

It is common practice for meat packers to place 600 to 1000 lb of dry ice in each carload of meat, not only for the additional refrigeration, but for the effect of CO_2 in reducing slime-producing organisms. Wholesale markets shipping meat cuts in boxes or barrels place a piece of dry ice on the bottom of each package and another piece on top. The area immediately adjacent to the piece of dry ice is, of course, rapidly cooled, and the cold CO_2 gas given off by the vaporizing dry ice diffuses and circulates throughout the box, thus keeping the contents uniformly cooled. Those boxes or barrels of meat then move by regular methods of transportation and arrive in excellent condition.

Where dry ice is used as an **auxiliary refrigerant** or in carload shipments, it is

FRED C. SEEFELDT, Author Chapter 43. Born 7/11/06 in Chicago, Ill. Educated at University of Illinois, BS, 1929. Formerly engaged in shop machine tool assembling and design of automotive drill fixtures with Ingersoll Milling Machine Company, Rockford, Ill.; manufacturing layouts and tool design, Stewart-Warner Corp., Chicago, Ill.; design of special manufacturing equipment, Western Electric Company, Chicago, Ill.; manufacturing layouts, Machinery Division, design of CO_2 manufacturing plants, Gas Plant Division, Liquid Carbonic Corporation.

Member, Amer. Soc. of Refrig. Engrs.; Compressed Gas Association.

At present, Sales Engineer, Carbon Dioxide Division, Liquid Carbonic Corporation, New York.

commonly applied either in a sheet-metal bunker mounted on the inside of the car, or in cloth bags hung from the ceiling of the car. Very often it is simply thrown into the end bunkers along with the water ice. Circulation of the air from the end bunkers keeps a fairly uniform concentration of CO_2 in the interior of the car. However, the use of a special dry-ice bunker is to be desired above the other methods, because a constant cold surface area is maintained. The rate of evaporation will be uniform instead of uncontrolled, as it is when hung in a sack or simply thrown into the end bunkers with the water ice.

In **Fig. 1** the method of using dry ice in barrelled meats is illustrated. There are many factors affecting the amount of refrigeration needed. The shipping agency must always use judgment in determining the amount of dry ice to be used. Some of the determining factors are:

1. Insulating value of package
2. Outside temperature
3. Time in transit
4. Quality of the product
5. Temperature of product before shipment.

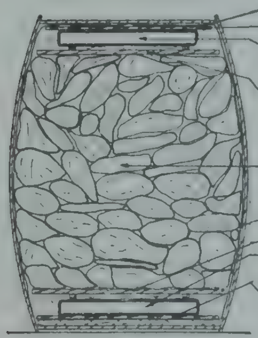

Fig. 1. Method of Using Dry Ice to Keep Meat in Good Condition when Not Shipped under Refrigeration. This Method of Packing Will Refrigerate the Meats for 24 hr.

A layer of fat is a good insulator; lean meat needs more ice. Liners for boxes and barrels are recommended. **Table 2** suggests amounts of dry ice to be used.

These figures are based on tests and the practical experiences of many meat packers. There is always a certain minimum amount of dry ice which must be used. Suppose the basis of calculation is, for example, beef as above at $\frac{1}{2}$ lb of dry ice per 100 lb of meat per hr. It is plain that $\frac{1}{2}$ lb of dry ice could not refrigerate 100 lb of beef for 1 hr even though 24 lb could refrigerate 100 lb of beef for 48 hr. This is true because the effect of the one piece is concentrated in too small a spot. Refrigerant must be placed at top and on the bottom to properly take care of heat leakage throughout the package. Five pounds of dry ice is the minimum for use in normal size containers.

Table 2. Amount of Dry Ice Required for Barrelled and Boxed Meats, per 100 lb of Meat, in lb

Hr. in transit	Beef	Pork	Fresh sausage	Cured meats
12	6	9	6	5
16	8	12	8	5
20	10	15	10	5
24	12	18	12	6
36	18	24	18	9
48	24	36	24	12

In the shipment of ice cream and other frozen foods, pieces of dry ice are placed inside the package along with the product **(Fig. 2)**.

Excellent corrugated containers are available for the shipment of ice cream and other frozen food products, and tables have been provided by the manufacturers showing the recommended dry ice quantity for a given time.

Many railroads have provided less-

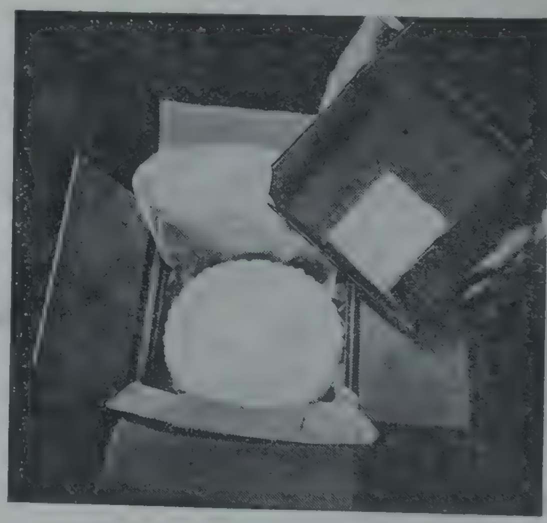

Fig. 2. Ice Cream Pie in Box. Note Carton Construction to Prevent Ice Resting on the Pie.

than-carload refrigerated boxes for the shipment of perishables—insulated boxes with dry-ice bunkers inside. The box moves in an ordinary freight car **(Fig. 3).**

In the cases of frozen foods where very low temperatures will not affect the lading, it is common practice to distribute full blocks of dry ice throughout the load in shipment on insulated trucks. To reduce the rate of heat transfer, leave the ice in the paper bags.

Controlled Temperature Refrigeration

In many applications of dry ice, the extreme low temperature obtained is of no consequence as in the shipment of frozen foods. However, where fresh foods are shipped and temperature of 35 to 40 F are required, some type of control must be used. This control may be obtained by the following methods:

1. Constant area of cold surface
2. Secondary refrigerant with constant evaporator surface
3. Secondary refrigerant with controlled rate of flow through system
4. Controlled rate of air flow over constant cold surface.

Fig. 3. Dry Ice Refrigerated L.C.L. Container Showing Double Bunker. For Fresh Foods, One Bunker only is Iced. For Frozen Foods Both Bunkers are Iced.

Through the use of better designed ice bunkers, insulation controls, and secondary refrigerants, dry ice may be used more economically and practically constant temperatures may be obtained.

Approximate temperature control can be obtained by the use of a metal bunker to hold the dry ice. The sides of the bunker are insulated so that the bottom surface acts as a constant cold area. If this area is of the proper size, calculated to absorb the heat leakage into the refrigerated space at a rate to maintain the desired temperature, then fairly accurate control is obtained.

The following applications will illustrate how equipment has been applied for practical control and uniform refrigeration throughout a given space:

Many truck operators handling fresh food in which a temperature of 35 to 40° is desired are using one or more sheet metal bunkers mounted at the ceiling having small fans for circulating cold air around the insulated truck body.

These bunkers have a capacity of one to four cakes of ice and are designed so that the air passes through a duct under the cold shelf, but not directly across the ice. In this way, more nearly constant refrigeration is obtained since the cold surface remains constant as the ice is reduced in size.

The circulating fans are usually operated directly from the truck or tractor batteries and some fans are thermostatically controlled. In other installations separate batteries are mounted on the trailer so it is independent of tractor.

These bunkers are inexpensive and may easily be removed during the winter months where refrigeration is not required so that weight is reduced and additional space is available.

Several types of more elaborate systems have also been developed in which manifolds for circulating secondary refrigerants are located along the upper side walls of

truck. The thermal system of circulating the secondary fluid is used on the smaller trucks, and thermostatically controlled pumps are used on the larger units.

The bunker is so arranged that it may be re-iced from a small outside door in truck body, and the secondary refrigerant surrounds the bunker for the transfer of refrigeration from the ice to the circulating fluid.

One factor which is frequently overlooked on truck refrigeration is allowing space for the circulation of cold air around the lading. By building in floor and wall racks it is impossible to block off these spaces and better results are obtained.

A new type of dry ice refrigerator has recently been introduced for dining car service and railroads which have tried same are quite enthusiastic about it. (See also Chapter 45.)

This unit consists of an insulated dry ice chamber which has a built-in manifold system through which Freon-12 is circulated by thermal action. A solenoid valve controls the flow of the chilled refrigerant between the dry ice chamber and the external evaporator located in the food chamber. This unit is very well designed so that it may be built into dining car construction and is made in capacities of 100, 150 and 200 lb of dry ice.

In a recent 24 hr test with one of these units, a leading railroad found that in spite of frequent opening of door during meal time, the temperature increased only from 32 to 42 degrees as a maximum variation and gradually returned to 32 F after the rush hours. The dry ice consumption was only 2 lb per hr.

Dry ice is especially advantageous as a source of refrigeration in the transportation field as it is not subject to failure because of the inherent vibration and is thus dependable, requires no maintenance, is simple and clean.

If you searched this chapter for something which was not found in it please let the editors know.

44. CONTROLLING THE ATMOSPHERE IN FOOD STORAGE ROOMS

Introduction

ONLY the most naive would assume that the only attribute of importance in the cold storage of foods was the **temperature.** This factor may be the most important single consideration, but the **nature of the atmosphere** and the **manipulation of the atmosphere** around many foods is of considerable importance.

This chapter will deal primarily with the importance of the atmosphere in the storage of certain fresh fruits, but some mention in this connection will be made with other foods. Some of the principles discussed would pertain to the storage of all fresh foods and others would apply only to specific foods.

Proper Atmospheric Distribution

Whether the atmosphere in a food storage room be air or some modified atmosphere, it is highly imperative to have good distribution of the desired atmosphere around all the containers in the storage room.

It is a "snare and a delusion" to look at a thermometer in the aisle of a cold storage room and assume that all of the stored food in the room is at that temperature! **The real issue revolves around the temperatures of the product at the center of the stack.** Some storage operators seem to be happier not knowing that it is taking 3 or 4 weeks instead of the desired 4 to 7 days to bring core temperatures of fruit down to 32 F after the fruit is brought into the room. Rapid removal of field heat is very important and cannot be accomplished unless there is good air distribution. As a generalization, one might say that there should be moving air passing by at least two sides of every container of fruit.

Stacking. There is no point in having an elaborate system for air distribution if poor stacking undoes all that the system is supposed to do. The writer has seen many examples of stacking in front of duct outlets or in front of diffuser outlets or inlets.

It is difficult to draw up rules for stacking because containers for fruit and other foods vary so widely. For example, apples may be stored in the western type box which has no openings for air passage. Or they may be packed in the northeastern type of box which has cleats on the ends which allow some air passage through even tightly packed boxes in a stack. They may be packed in baskets which, when stacked, allow ample circulation through the stack. They may be stacked in unlidded field crates which allow some air movement across the tops of the fruit.

Rules for stacking western boxes of fruit (apples and pears) have been fairly well standardized. Lines are painted on the floor of the storage rooms to indicate the spaces for placing rows of boxes.[1] A uniform spacing of 2 to 3 in. between rows has been found to be as practical as wider spacing, if there is sufficient head room between the boxes and the ceiling. The rows should be so laid out that the general direction of air movement is along the rows instead of across them.

Stacking against outside walls should be avoided since there is always heat leakage thru the walls into the room during the warmer months. A 4 to 6 in. spacing at

ROBERT M. SMOCK, Author Chapter 44. Born 10/21/08, in Erie, Pa. Educated at Muskingum College, BS, 1930; Ohio State University, BS in Agric., 1931; MS, 1932; Ph.D, 1934; special work Univ. of Chicago, 1934. Formerly, Junior Pomologist, University of California, 1934–37; Assistant, Associate and Professor, Cornell University, 1937 to date.

Author of six bulletins from the Cornell University Agric. Experiment Station; numerous articles in Proc. Amer. Soc. Hort. Sci.; co-author "Apples: Their Chemistry, Physiology and Technology," published by Interscience Publishing Company, New York, N.Y.; six articles in *Refrig. Eng.;* several in *Food Ind.;* Chapter 41, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. Hort. Sci.; Amer. Soc. of Refrig. Engrs.

At present, Professor of Pomology, Cornell University, Ithaca, New York.

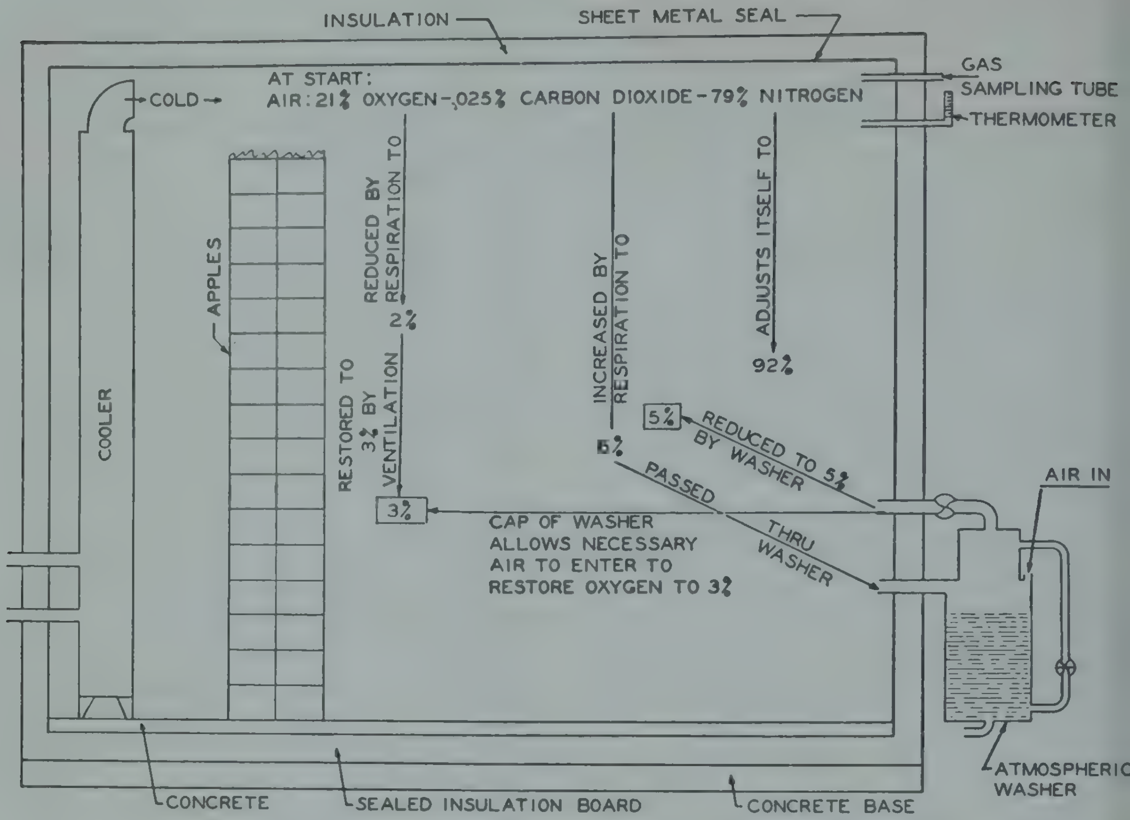

Fig. 1. Diagrammatic Representation of What Happens in a Controlled Atmosphere Storage.

the side walls is desirable. A side rail on the walls can prevent stacking against the walls. On a ground floor it usually pays to place strips between the floor and the bottom tier of boxes.

With unpacked apples in northeastern boxes or field crates it is probably not as important to leave this full 3-in. spacing, but it is important to make sure that air can get past at least two sides of each container. Lidded boxes packed on their sides must be spaced so that air can move past each side of the box. For more details on stacking fruit see Chapter 15.

The exact method of stacking may depend in part not only in the type of container used but also in the method of air distribution used. If a gravity air flow system is used with cooling coils, spacing of containers is even more important than with forced air circulation. With some types of forced air circulation, excessive spacing between the rows may do more harm than good, since air is allowed to bypass the containers. The use of pallets in the storage room sets up still another problem.

One system of stacking and air distribution that is in use and that has been tested experimentally[2] will be described briefly. The air is taken down the length of the room with a central duct. Outlets along the sides of the duct direct the air out across the top of the stack. A four-inch spacing at the side walls acts as a plenum and builds up a slight pressure. The air is then forced back thru the stack. The boxes must be so spaced that air can get past them on two sides. The aisle acts as a return duct to the blowers. The boxes must be stacked parallel to the aisles so that the spaces between boxes act as channels from the wall space to the aisle.

In the situation just described the aisle served a useful purpose in the air distribution set-up as a return duct. In some cases, aisles upset an otherwise good set-up for air distribution. Aisles running parallel to the air flow from ducts may allow channeling. Since such aisles are often desirable

from a handling standpoint, curtains should be hung in them during the period of field heat removal. Alleys running perpendicular to the air flow from the air distribution system may allow short circuiting of air. These alleys can be bridged over the top during the "pull-down" period.

Since almost every room presents a separate problem, study is often necessary to decide how best to distribute the air, keeping in mind the general principles discussed here.

Duct work. It is sometimes assumed that because a blower has a high cfm rating that air must go to all parts of the room. Actual study[2] has shown that without duct work the air tended to become turbulent at the mid-portion of the room and short circuit back to the blowers. The front corners of the room (the blowers being at the front of the room) were completely "dead." Duct work must be carefully designed so that there is an equal static pressure along its whole length. Outlets from ducts or diffusers must be designed so that each delivers its desired amount of air and distributes that air as uniformly as possible throughout the cooled space. The writer has observed duct work in which air was actually being aspirated **into** the duct outlets from the room.

Relative Humidity

A very important aspect of the atmosphere in the storage of foods is the relative humidity. Humidity requirements of various foods are described in Chapter 14.

Carbon Dioxide and Oxygen

Apples. Fruits are living organisms which carry on respiration in a manner similar to that of animals except that they do not breathe in the same sense. Carbohydrates are oxidized in **respiration** with the subsequent production of carbon dioxide, heat, and water vapor. Respiration is diminished in intensity not only by lowering the temperature, as in cold storage, but also by reducing the amount of oxygen and allowing the carbon dioxide to accumulate.

By use of gas tight structures and controlled ventilation, the desired proportions of carbon dioxide and oxygen can be attained. With some varieties of foodstuffs it may be desirable to have independent control of carbon dioxide and oxygen. Control of these two gases by regulated ventilation will provide the necessary atmosphere only when the two gases together constitute 21 percent of the atmosphere. The method of regulating these proportions of gases is discussed later in this chapter.

The technique evolved by Kidd and West[3] combines low temperatures and atmospheric control. The maximum temperature used with most varieties of apples and pears is 40 F. Controlled atmosphere storage should not be regarded as a substitute for cold storage but rather a supplement to it in certain special cases.

Advantages. Many varieties of apples are subject to low temperature troubles like brown core, internal browning, soggy breakdown, soft scald, and brown heart. By using temperatures from 38 to 40 F and the proper atmosphere, these varieties can be kept just as long if not longer than in ordinary air at 32 F and will be free from these disorders. (See Chapter 19.)

The **storage life** of certain varieties is markedly increased when the right atmosphere is used, even at temperatures as high as 40 F. Several months can be added to the ordinary storage life of certain American varieties of apples. With some varieties of pears temperatures as low as 34 F can be used and from five to six months can be added to their ordinary storage life.[5]

A specific effect of carbon dioxide is to retard greatly the normal green to yellow changes in apples and pears. This is of particular importance with some varieties of green cooking apples. A very marked residual effect of the storage treatment is often noted as a result of this technique. Fruit removed from controlled atmosphere storage will remain marketable much longer than that removed from cold storage.

Because of the relatively high carbon dioxide and low oxygen concentrations, **mold growth** seems to be inhibited. Hence somewhat higher humidities can be used than in cold storage.

Disadvantages. Because of the danger of suffocation and the loss of the required atmosphere in the chamber, the operator cannot enter the storage room for inspection of fruit or manipulation of the equip-

Fig. 2. Interior of a Controlled Atmosphere Storage Room, Showing Diffuser in Foreground and Sheet Metal Lining of Room.

ment. It is difficult to make buildings gas tight. Moreover, controlled atmosphere storage is not universally applicable to all fruits or all varieties of any one fruit.

The double effect of very low storage temperatures and atmospheric control does not always give the full theoretical benefit that might be expected. With certain varieties, concentrations of carbon dioxide as low as 2 percent are toxic at a temperature of 32 F. Because of this toxicity factor, with many fruits the temperature must be held as high as 40 F. Different apple and pear varieties have different specific atmospheric and temperature requirements for long time storage. This necessitates the use of different chambers with varieties of different requirements.

Operation and management of controlled atmosphere storage. Space does not permit a full description of the construction, operation, and management of a controlled atmosphere storage for apples. Such a description may be had by writing to the Mailing Room of the College of Agriculture, Cornell University, Ithaca, N. Y. Ask for Cornell Extension Bulletin 759.

Pears. Studies in California[4] and unpublished work at Cornell show that Bartlett pears and certain other varieties respond very well to controlled atmosphere storage at 32 F. An atmosphere of 5 percent carbon dioxide and 2–3 percent oxygen adds several months to the storage life of several varieties.

Stone fruits. Attempts at long time storage of the stone fruits such as peaches, plums, and apricots in controlled atmosphere storage have been unsuccessful.[5] The use of **carbon dioxide treatment** for relatively short periods, however, has been very successful with some of the stone fruits.[6] A high percentage of the sweet cherries shipped from the west coast are shipped with an atmosphere of 15–30 percent carbon dioxide in the refrigerator car. Dry ice is usually used as the source of the carbon dioxide in refrigerated transit. Because of the leakiness of the cars the concentration does not stay very high for more than a few days, but considerable benefit is obtained nevertheless.

Small fruits. Both experimental and commercial trials have shown the possibilities of using high carbon dioxide atmospheres during short storage periods with strawberries and red raspberries.[7,8] These carbon dioxide treatments involve concentrations ranging from 20 to 40 percent and temperatures of 45 to 55 F. Carbon dioxide storage of these fruits will add as much as three or four days to the storage life of these very perishable fruits.

Citrus. While some experimental work has been done with the storage of citrus in low oxygen or high carbon dioxide atmospheres, as yet there has been no commercial development along this line. Some of the citrus fruits such as lemons are very sensitive to carbon dioxide.

Vegetables. While some of the vegetables can have their storage life considerably lengthened by the use of very low oxygen atmospheres, there has been no

commercial development as yet. Some vegetables are extremely sensitive to small amounts of carbon dioxide.

Meats. The initial impetus for the use of carbon dioxide came about from changes in meat demand in England. Years ago there was an established demand for frozen meat which could be met by producers in Australia and New Zealand. When improved methods permitted fresh beef being supplied, it became possible for South American producers to undersell the more remote colonial producers, who were thus driven to find a new method of shipping fresh meat to England. The source of supply of all foods is remote from England, promoting use of any method which will extend the time of storage. In the United States, the source being close by, the controlling element is, however, quality. This method offers a means of prolonging the storage of meat, as it is often economically desirable to do, for the production of meats, especially pork, has an annual cycle.

Most of the organisms injurious to meat are inhibited in CO_2 concentrations of 20 percent and partially at lower ones. At higher concentrations the meat suffers discoloration, lean areas becoming brown and fatty ones pallid due to the conversion of red pigment of the tissues and blood, oxyhaemoglobin, to the brown methaemoglobin. This change is greatly influenced by oxygen, but it goes on much the same in spite of the carbon dioxide since the vapor pressure of the oxygen is still high. Early experiments in shipment showed it possible to sell meat 49 days after slaughter in competition with regular chilled beef. The temperature in the hold in shipment was 28.5 F in this case. The utility of CO_2 in meat storage is more marked at temperatures below the optimum for the growth of the organism.

The feasibility of using this method is, of course, affected by the action of the gas on the substance of the food itself, one criterion important with meat being changes in color or "bloom." The color of fresh beef has been studied by Brooks.[9] Change in fresh lean meat takes place in the surface layer of a tissue containing dissolved oxygen. Carbon dioxide concentrations tested at 32 F and 99 relative humidity showed that gas has no very marked effect on the penetration of oxygen. At the same time the carbon dioxide may directly affect the rate of methaemoglobin formation. A decrease in pH or in the oxygen pressure increases the rate of oxidation of the haemoglobin. Thus high concentrations of the gas tend to produce rapid discoloration but there is no effect up to 20 percent. Growth of bacteria on muscle can also change its color. (See Chapter 24 for effects of drying.)

Chemical changes taking place in the meat, especially the fat, are of equal interest in establishing limitations of this method. Generally it appears that storage in carbon dioxide has an inhibiting effect on the tendency to taint which otherwise takes place, the optimum value being noted by Lea[10] at 20 percent. The inhibiting effect of gas on tainting is more effective the earlier it is applied after slaughter. At high humidities it doubles the time required to produce taint.

Further studies on the shipment of beef indicate that chief cause of waste in ordinary shipment is the attack of the bacteria of the *Achromobacter* family on the moist surface tissues, rather than by the growth of molds, which compose a small part of the initial contamination. The duration of any kind of storage is determined by the initial bacterial count on the beef as produced. Carbon dioxide so inhibits the activity of the bacteria mentioned as to prolong storage about 40 percent beyond that otherwise possible at the same temperature. Storage at 10 percent carbon dioxide for periods up to 45 days is possible.[11]

Experiments made in Russia indicate the effects shown in **Table 1** on the keeping of beef.[12]

Table 1. Storage Tests on Beef
Number of days until equivalent signs of spoilage appeared

CO_2%	Temperature, F	
	41	32
0	4	6
25	6	14
50	15	23
100	19	31+

Considerable interest has been shown in gas storage of bacon, the Food Investigation Board having done experimental work through E. H. Callow. Normally bacon cannot be stored above 32 F without taint and change of color, while bacon which has been frozen becomes rancid. Rancidity of smoked bacon appears after three months in frozen storage. Unsmoked bacon has been stored at 32 F for four months in carbon dioxide and regarded as equal to the fresh product. The loss in weight occurring in 8 weeks storage in air at 26.6 F was equal to 19 percent. Bacon freezes at about 23° and if kept below that point shows a greatly reduced loss in air. In carbon dioxide the loss was only 1.8 percent in this period at 28° and 0.4 percent at 14 F.

Investigations with pork were nonconclusive. Carbon dioxide tends to injure the skin of fresh pork.

Fish. The Russian investigators were particularly interested in fish and they found storage in carbon dioxide desirable at temperatures from 32 to 50 F, as well as for frozen fish at 18 F. There are no changes in quality, color or taste due to absorption of the gas, but fish showed a discoloration about the gills in atmospheres of less than 50 percent. The gas treatment is more effective at the lower temperatures. **Table 2** gives some of the results, indicating that a 100 percent concentration is most favorable at 41°. However at 32 F and 62 F concentration at 50% and above is most favorable.

Table 2. Gas Storage of Fish
Number of days before equivalent signs of spoilage appeared

CO_2%	Temperature, F		
	32	41	62
0	5	2	1
25	15	6	2
50	21	9	6
100	21+	15+	6

Eggs and Dairy Products. Tests to show a comparison of three methods of egg storage have been undertaken by Moran: (1) Cold storage with control of humidity, and gas storage of 2 percent carbon dioxide, (2) refrigeration and control of humidity and gas storage with 60 to 100 percent carbon dioxide, (3) refrigeration and 100 percent humidity. The temperature range in all cases was 29 to 32 F. The second method showed decided advantages over the first in preventing storage taste, but the air cell in both cases was large. The third method tends to make the egg white watery but keeps the air cell small, and is superior in prevention of rots.[13]

Butter and milk stored in CO_2 acquire a slightly acid taste, the surface layers being especially affected due to absorption of the carbonic gas. Milk so stored will regain its normal taste upon exposure to fresh air. Data on length of storage life did not appear from the investigations where this was established.[12]

In their most recent report Kidd and Moran speak of a maximum of 10 percent CO_2 for long storage of meat, 30 percent in the case of fish and 60 percent or more in the case of eggs. Gas works better for living substances such as fruits. A special problem of control is introduced in the matter of humidity. The optimum amount of drying to produce just the right color has yet to be determined in the case of meat, but some drying is not undesirable. But molds, yeast and bacteria cease to grow when their water content is in equilibrium with the relative humidities of the atmosphere present at approximately 85, 90 and 96 percent respectively.

Ethylene

It has been known for a good many years that the ripening rate of a great many fruits could be stimulated by the addition of ethylene to the atmosphere. More recently it has been found that ripe fruits give off ethylene. It has been found for example that even a rather small percentage of ripe apples in a storage room will stimulate the ripening of less ripe apples in the room. A full description of the conditions required to get this ethylene effect of ripe fruit has been published.[14]

One way to get around this problem is to segregate fruit in storage. That is, the riper fruit should be stored in separate rooms, and sold early. The prime fruit

should be stored separately and kept for the late market. This type of segregation is not always feasible, however.

A second way to solve the problem would be to ventilate the storage. This practice is only feasible in lemon storage. Lemons are stored at a high temperature and frequent ventilation with outside air does not greatly increase the refrigerating load (see Chapter 16). Ventilation as a means of removing ethylene is almost prohibitive in cost with fruits like apples and pears because the critical period is the first month of storage and outside temperatures are high at that time.

The most reasonable way to try to solve the ethylene problem in apple storages is to practice **air purification** with coconut shell carbon. Work at Cornell[15] and Washington State[16] has shown that purification of the storage atmosphere with this type of carbon would add about a month to the storage life of a number of varieties. A large number of apple storages are now equipped for air purification. This device is used not only in ordinary cold storage of apples but in controlled atmosphere storages as well.

One common method involves the use of 6–14 mesh coconut shell carbon enclosed in perforated canisters containing about 1½ lb of carbon each. Four canisters are employed per 1000 bushel of capacity. Air flow thru the canisters is at the rate of 25–30 cfm per canister. The purified air is directed into the air distribution system so that it is well directed to all parts of the storage room. A tray unit containing the carbon has been designed.[17] This unit has the disadvantage of being bulky. It is also extremely important in this type of unit that the beds of carbon be kept absolutely level to prevent channeling and uneven distribution of air thru the carbon. A third type of unit employs vertical trays or beds with the carbon confined tightly on either side of the tray.

Air purification shows promise of being helpful in pear storage for the lengthening of storage life. Work at Oregon State[18] has shown that the life of Anjou pears could be considerably extended. A number of commercial trials are being made with other varieties such as Bartlett in Oregon and Washington.

No experimental work has been done to date to show the advantages if any of air purification with the **stone fruits.**

When the costs of initial outlay, power, reactivation charges are pro-rated over a five-year period the cost per bushel is about 1½ cents per bushel per season.

Apple Scald Gases

The apple scald disease is caused by an accumulation of certain gases around the fruits. These gases are given off by the fruits themselves and actually "burn" the skin. This storage disease has been reduced by the use of oiled paper (15% mineral oil) either as fruit wraps or as shredded paper mixed with the fruit at the rate of ½ lb per box. Air purification as described under "ethylene" has been found to reduce scald about as well as oiled paper and is cheaper to use.[15] In a bad scald year it will not control the disease any more than oiled paper will, however.

Storage Odors

Contamination of foods by undesirable odors in the storage room does occur under some conditions. These odors may be from several sources. 1. building materials; 2. contamination of the storage space or containers with micro-organisms; 3. other foods in the room. The problem of odor contamination of foods in storage is primarily one of **prevention.** Building materials which have an odor should be avoided. The growth of micro-organisms such as surface molds, slime producing bacteria and others can be avoided in large part by good plant **sanitation.** In some instances, container materials are treated with chemicals to prevent the growth of micro-organisms (see Chapter 17). Cross contamination of odors of one food by another can be avoided by segregated storage. There are reasons for such segregation aside from possible cross transfer of odors. Apples and potatoes have different temperature requirements. Apples and onions have different relative humidity requirements.

In some cases, however, odor problems are faced and the question arises as to how they can be dealt with.

Eggs. Odor absorption by eggs can occur in some instances. Undesirable odors in

eggs are not necessarily due to odor absorption, however (see Chapter 17). The proper use of ozone (Chapter 20) will keep down surface molds that would otherwise appear in high relative humidity storage of eggs. The odors of such molds can be taken up by eggs and thus affect their quality. Other odors that may occur in egg storage may arise from the container, flat, or filler material. As nearly odorless materials should be used as is possible. Air purification with activated carbon (see ethylene removal) has been found effective experimentally in reducing the odor level in egg storage.[19] Unless surface molds were involved ozone did not reduce the actual odor level in egg storage, it merely masked the odors that were present.

Fruits. Ozone has been found effective in reducing the odor level in fruit storage when surface molds were the source of the foul odors. In other cases, ozone merely masked the odors of various fruits. Air purification with activated coconut shell carbon was found experimentally to be of value in reducing the odor or volatile level of such fruits as apples, pears, and oranges. This means that one might get away without cross contamination of odors among the fruits by means of air purification with carbon, but the argument in favor of segregation in storage still holds.

Vegetables. Air purification with activated coconut shell carbon was found experimentally and in limited commercial trials to effectively reduce the odor and volatile level of onions, cabbage, and potatoes in storage.[20] Ozone was of no value in this connection.

Fish. In very limited experimental trials air purification with coconut shell carbon was found to reduce the odors of fish in storage. Specially prepared carbon may be required to remove strong fish odors.

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If you searched this chapter for something which was not found in it, please let the editors know.

45. REFRIGERATION OF FOOD ON RAILROAD DINING CARS

RAILROAD interest in mechanical refrigeration for diners and other cars having food storage refrigerators dates back to 1925. At that time, ¼ hp SO_2 condensing units with water cooled condensers, and ammonia and CO_2 machines of 1 hp and larger were all the industry had to offer. Water cooled condensing units are impractical on a railroad car due to the limited amount of water carried.

In 1926, SO_2 units of ¼ hp and upward with air cooled condensers were developed. Several railroads at that time made trial installations. The trial installations indicated that three major problems would have to be overcome:

1. Lack of power, especially when cars were not in motion
2. Extremely severe operating conditions
3. Lack of space for cooling unit and condensing units.

The cars on which early dining car equipment was installed used 32 volt DC systems provided with 400 to 600 ampere hour batteries and two to five KW axle-driven generators. The above batteries and generators had to supply current for fans and lights as well as the mechanical refrigeration system. Because of the very limited power supply, it became necessary to provide standby power whenever the cars were idle for more than just a few hours. The power supply has improved considerably in the past few years. 20 and 30 KW generators and larger batteries are now available. System voltages are 36–72 or 126 volts DC or 110–220 volts AC, AC being supplied through power inverters of 2 to 6.5 KW or engine-driven power plants.

CLIFFORD E. P. SMITH, Author Chapter 45. Born 4/8/06, in Millstadt, Ill. Educated at Washington University. Formerly, Experimental Engineer, Baldor Electric and Century Electric Company, St. Louis, Mo., 1923–29; Assistant Service Manager, Kelvinator, Inc., St. Louis, Mo., 1929–32; Air Conditioning Service Supervisor, Frigidaire Division, St. Louis Branch, 1932–36; Instructor and Field Service Engineer, Service Dept., Frigidaire Division, General Motors Corp., Dayton, Ohio, 1936–45; Sales Engineer, Railroad Air Conditioning and Dining Car Equipment, Direct Factory Sales Dept., Frigidaire Division, General Motors Corp., Dayton, Ohio, 1945 to date.

Contributor to service manuals and technical information, Frigidaire Division, General Motors Corp., Dayton, Ohio. Member, Amer. Soc. of Refrig. Engrs.

At present, Sales Engineer, Railroad Air Conditioning and Dining Car Equipment, Direct Factory Sales Dept., Frigidaire Division, General Motors Corp., Dayton, Ohio.

Operating conditions on a dining car are extremely severe. Kitchen temperatures have been known to be as high as 120 F and the temperature under the car as high as 140 F. During meal times, the service on the fixtures is very heavy and the fixtures often stand open for long periods. The refrigerators must be stocked with sufficient provisions to handle from 100 to 300 passengers, many taking three meals a day.

The diner on a feature train usually carries the following assortment of foods requiring refrigeration. As these supplies are depleted, they are replaced enroute.

300 lb	Meats such as steaks, chops, roasts, ham, bacon and cold cuts
50 lb	Fowl
60 lb	Fresh Fish
2–3 cases	Eggs
40 qts	Milk
25 qts	Cream
10 lb	Cheese
20 pkgs	Frozen Food
12 lb	Butter
10 gal	Ice Cream
2 cases	Concentrated fruit juices or 2 crates oranges
10 gal	Prepared soup
6–8 cases	Soft drinks
4 cases	Beer
200 lb	Potatoes
2 crates	Salad vegetables
40 loaves	Bread

The kitchens and pantries of diners are of necessity most compact. The fixtures must be located and arranged to be as con-

venient as possible for the waiters and cooks. It is obvious that space is at a premium. Most refrigerated fixtures are high (7 ft) and shallow in depth (2 to 3 ft) with widths of 3 to 5 ft or the other extreme of long (5 to 7 ft) low (3 ft) and shallow (2 ft). This makes it difficult to provide proper size coils and baffles to induce air circulation. Special attention to evaporators is required as icing up may be severe, unless refrigerant temperatures are kept as high as possible, consistent with desired fixture temperatures. Rapid temperature recovery is also important.

The condensing units can be located in a suitable compartment below the floors of the cars (See **Figs. 1** and **5**) under the various fixtures inside the cars **(Fig. 2)** or above the ceiling **(Fig. 4).** The individual condensing unit under each fixture is somewhat higher in first cost, space requirements and operating wattage; however, the advantages of more positive temperature control, ease of maintenance, etc. will more than offset this. Where space below the fixture is not available, the unit is located under the car or above the ceiling.

General Specifications Concerning Mechanical Refrigeration for Railway Dining Car Equipment

Temperatures

1. Average maximum **Outside** ambient temperatures:

   West of Chicago 110 F
   East of Chicago 100 F

   This applies to both overhead and under car locations of the condensing unit. These figures are general. Where other temperatures are specified, corrections should be made in accordance with the prevailing conditions. If the condensing unit is located within the occupied sections of the car, special consideration must be given. The effect of enclosures or compartments upon condensing unit performance must be considered. Condensing air temperature of 110 F is good design practice.

   The condensing unit ambient temperture must be maintained at 50 F or above at all times. This is necessary for proper operation of the refrigeration system during cold weather, as under car temperatures of 20 to 50 F below zero are not uncommon on northern railroads. During summer weather, maximum possible ventilation should be provided to the units to get best performance.

2. Average maximum **Inside** car or fixture ambient temperatures in degrees F. Note particularly the temperatures prevailing when cars are idle in the yards.

	West of Chicago	*East of Chicago*
Kitchen with poor ventilation and no air conditioning	130°	120°
Kitchen with average ventilation and no air conditioning	120°	110°
Kitchen with extra ventilation or some air conditioning	110–115°	100–105°
Kitchen during idle periods in the yards with no service	115°	105°
Pantry with poor ventilation and no air conditioning	120°	110°
Pantry with average ventilation and no air conditioning	110°	100°
Pantry with extra ventilation or some air conditioning	100°	90°
Pantry during idle periods in the yards with no service	115°	105°
Dining section with standard air conditioning	90–100°	90°
Dining section during idle periods in yard with no service	115°	105°

3. Unless otherwise agreed, fixture temperatures will be assumed as follows:

Fixture	*Degrees F*
Low temperature boxes	0–15
Storage boxes for bottled goods, vegetables & other produce	38–48
Meat storage boxes	36–46
Fish storage compartments	32–38
Ice cube storage compartments	34–38

For design calculations, use minimum fixture temperatures shown. Due to the tendency of wet ice cubes to stick together when stored below the freezing point, the storage of ice cubes at 34 to 38 F is recommended. Meltage at these temperatures will be negligible.

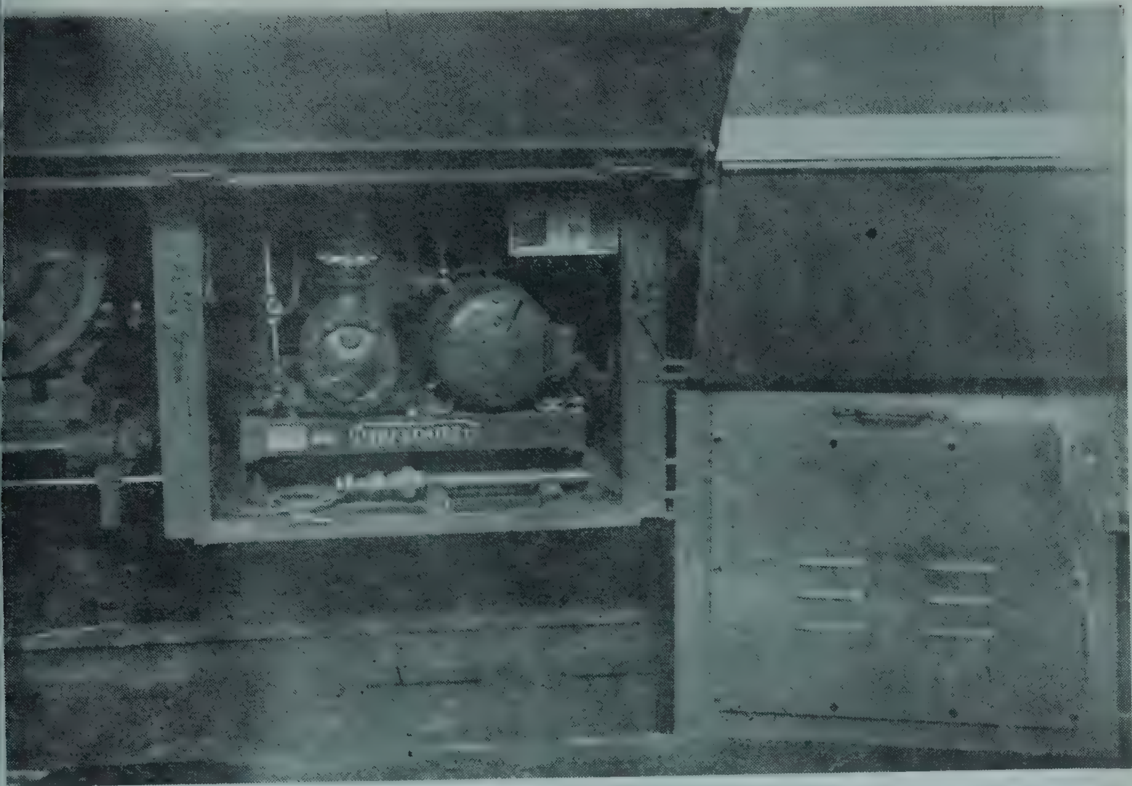


Fig. 1. Typical Undercar Condensing Unit Installation Showing Steam Valve Control Unit in Front for Maintaining Proper Winter Operating Temperatures.

These temperature ranges may appear to be rather wide. However, dining car fixtures are subject to very heavy service during meal periods with the refrigerator doors open constantly. Closer control during service cannot be expected.

Fixture Construction and Calculation of Refrigeration Loads

1. Fixture insulation should be based upon minimum thickness as follows: For refrigerators with 36 to 48 F temperatures, 3 in. thickness for ambient temperatures up to and including 110 F; above 110 F, 4 in. thickness will be required. For low temperature cabinets with 0–15 F temperatures, 4 in. thickness for ambient temperatures up to and including 110 F; 5 in. of insulation will be required for temperatures above 110 F.
2. All heat leak calculations should be based upon the exterior surface area of each fixture, the temperature difference between the ambients and the fixture temperatures shown above, and the proper transmission factor in Btu/hr/sq ft/°F temperature difference for the insulation selected. When a transmission factor higher than .32 for 1 in. thickness is involved, the thickness of the insulation should be increased at least an additional inch.
3. Predetermined allowances should be made for the type of service that will be imposed upon each fixture. This service is usually classified as light, medium or heavy, but does not include peak conditions that would be imposed by loading the fixture with warm products. All produce or food going into fixtures should be precooled or frozen and reduced to the temperature at which it is to be stored before being loaded.
4. Ice freezing, water cooling and bottle cooling load requirements shall be specified in each instance.
   a. Unless otherwise specified, ice freezing is based upon 90 F water into the trays with an average of approximately 4 hours' freezing time at rated line voltage.
   b. Unless otherwise specified, water cooling will be based upon tempera-

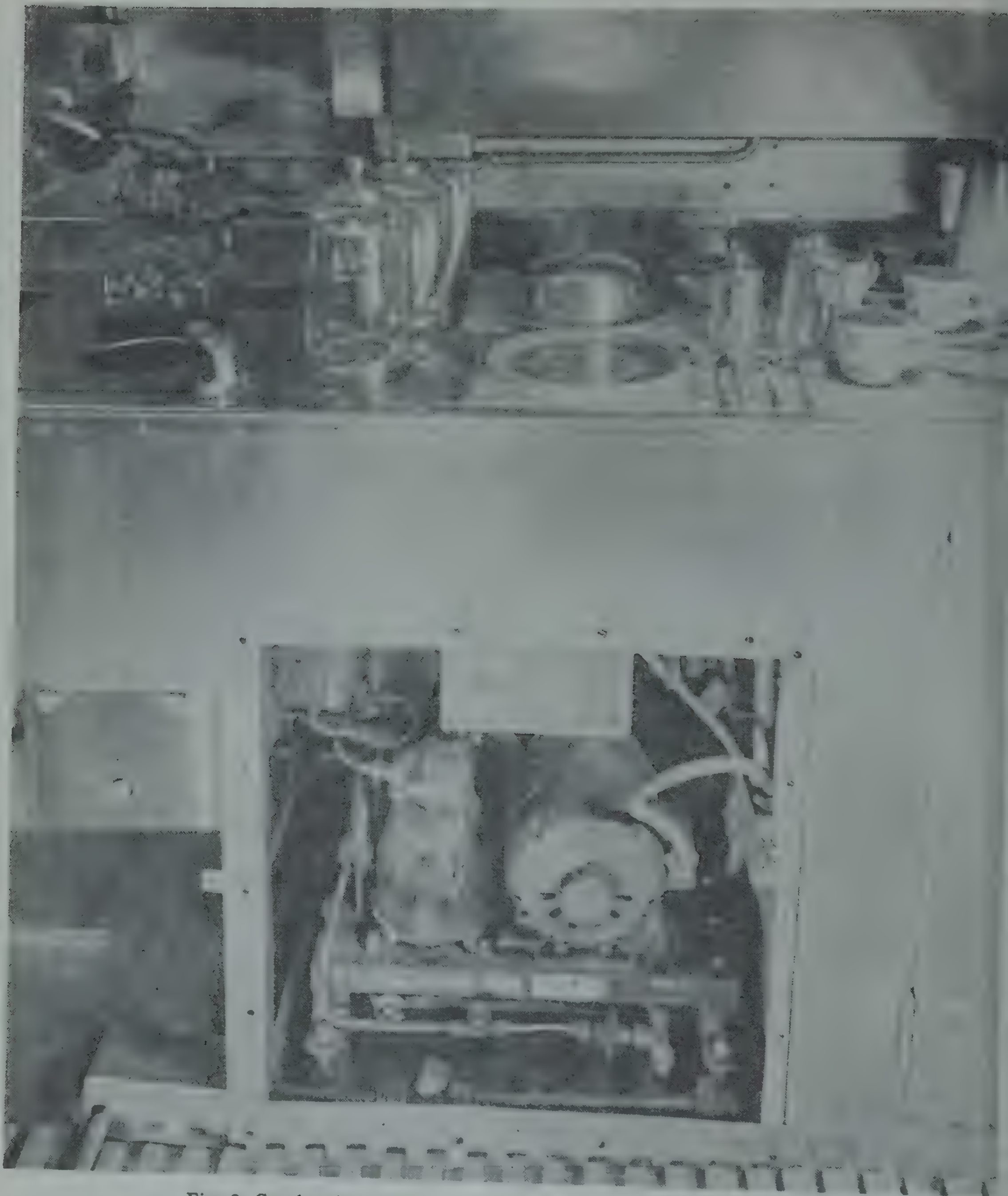


Fig. 2. Condensing Unit Installed in Car Under Kitchen Fixture.

tures of 90 F water in and 50 F water out.

c. Unless otherwise specified, bottle cooling will be based upon 90–100 F temperature in and 40–50 F bottles out with cooling periods of 4 hr and up for forced air evaporators and 6 hr and up with gravity evaporators, both depending upon the loading conditions.

5. Less than the insulation thickness shown in Item 1 will probably result in condensation on the outside shell due to the high kitchen humidities. Where a limited electrical power supply requires a reduction of refrigeration loads, the above recommended thicknesses of insulation should be increased by at least 1 in.
6. All low temperature cabinets should be

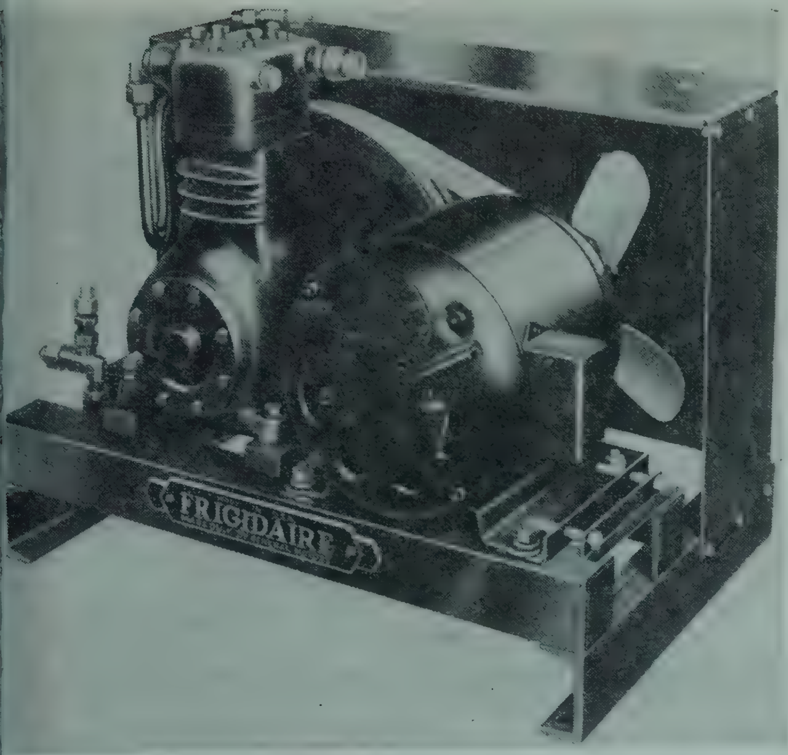


Fig. 3. Typical Railway Type Recripocating Condensing Unit.

of the top-opening type. Exceptions will require special consideration. The outer shell of all low temperature cabinets must be completely sealed to prevent infiltration of moisture into the insulation.

7. The insulation of all fixtures must be also sealed against the infiltration of moisture and should be of such a nature that it will not settle, due to vibration of the car.
8. All doors and lids of fixtures should be properly gasketed, insulated and sealed.

Selection of Condensing Units

1. Ice freezing, water cooling or other peak load conditions are determined on the basis of 100% running time.
2. Heat leak and service loads are determined on the basis of 18 hr running time at rated line voltage with average maximum ambient temperature and minimum fixture temperature conditions.

Effects of Varying Line Voltage and Overload Conditions

1. Most compressors will be equipped with DC motors, the speed of which will vary with actul operating voltage. Therefore, the unit may operate continuously on low battery with some increase in fixture temperature.
2. If the refrigeration system is started with warm cabinets, the pull-down time and temperatures for DC systems will be uncertain if the voltage at the motor falls below 27 volts, 54 volts or 97 volts for 36-volt, 72-volt and 126-volt systems, respectively.
3. With average service and average maximum temperature conditions the desired cabinet temperatures for DC systems may not be maintained if the voltage at the motor is below 27 volts, 54 volts, or 97 volts for 36-volt, 72-volt and 126-volt systems, respectively.
4. Overload conditions beyond the average maximum temperature and service specified above may be accompanied by a corresponding rise in fixture temperatures depending upon the severity of the conditions.

Condensing Unit Installation and Controls
(See **Fig. 3**)

1. Condensing units must be located and housed to maintain the desired minimum (50 F) winter ambient temperature, and to provide sufficient air circulation so that ample air is provided for proper performance at average maximum summer ambients.
2. Condensing units with $\frac{3}{4}$ hp motor or larger require protection by a high pressure cutout. (Setting 240 lb–245 lb.) Smaller units need not be so equipped.
3. Pressure switches, safety switches, and overload protectors should be mounted as close to the condensing unit as possible, in the same compartment, so that the overload will be sensitive to actual operating temperatures.

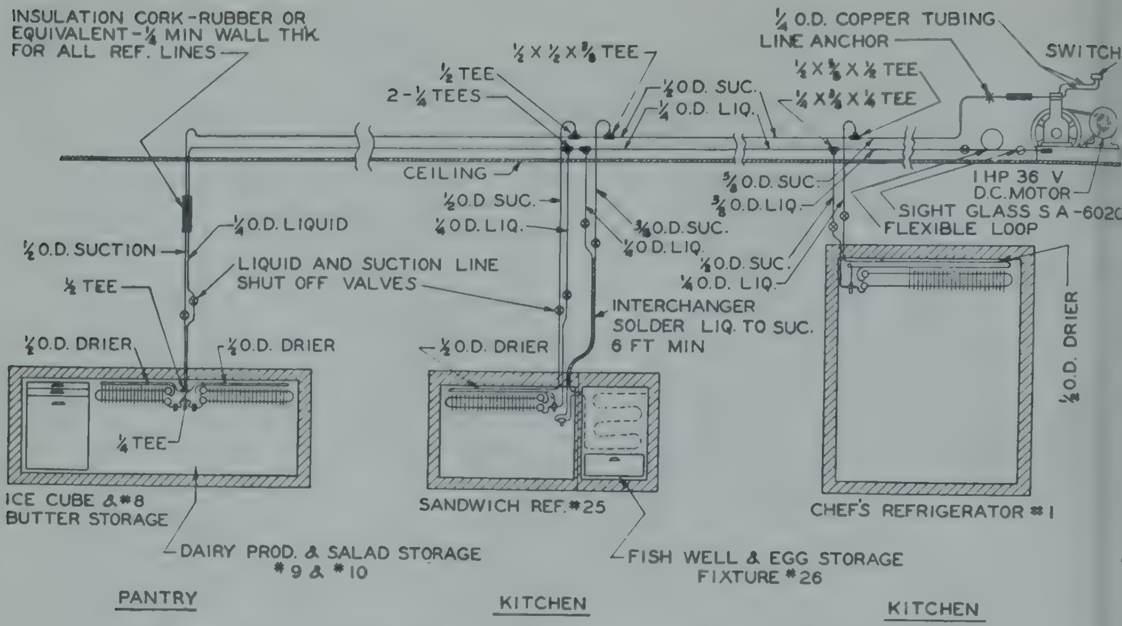


Fig. 4. Typical Multiple System with Condensing Unit Mounted Overhead.

4. Condensing unit should be installed on semi-rigid mountings for the absorption of shock and vibration. Mountings of rubber bonded to steel retainers or attachment members are preferred.

The maximum impact or shock on a railroad car due to car coupling, etc., is reported at 10 g. Suitable rubber mountings soften this impact on the equipment to about 4 g. The mountings themselves must, therefore, withstand occasional impacts approaching 10 g. Assuming a condensing unit weight of 260 lb, distributing a weight of 65 lb on each of four mountings, impact loads approximating 650 lb can be expected on the individual mountings. Movement under these conditions should be limited to $\frac{1}{8}$ in. at the mounting. Vibrations and impacts due to roll, pitch and road shock with normal car movement are indeterminate. Mountings under such conditions should allow for movement of no more than $\frac{1}{16}$ in.

Normal vibration cycles or pulsations due to the operation of the compressor occur at the frequency of the compressor speed which is normally 400 to 1600 rpm. It is practically impossible to use mountings with sufficient flexibility to absorb these low frequency pulsations, and at the same time maintain the necessary stability on a moving car. Experience indicates that the low frequency and inertia under those conditions can best be dealt with by minimizing the movement of the condensing unit on the mountings. The general structural ruggedness of the cars in which these compressors are to be mounted makes the inertia effects on the car almost negligible.

In all instances the choice of mountings shall be such as to insure the maximum life of the inter-connecting refrigerant lines or tubing with due respect for the following:

a. Recurring oscillations from normal compressor operation
b. Vibrations and shock due to normal car movement
c. Maximum shock of impact with worst known conditions.

5. Flexible sections of tubing to be installed at the condensing unit are recommended for all refrigerant lines. Soft copper tubing of $\frac{3}{8}$ in O.D. and smaller may be formed with a loop of sufficient size to provide flexibility as required by the condensing unit mountings.
6. Noises from the condensing unit motor will, generally speaking, be in the higher

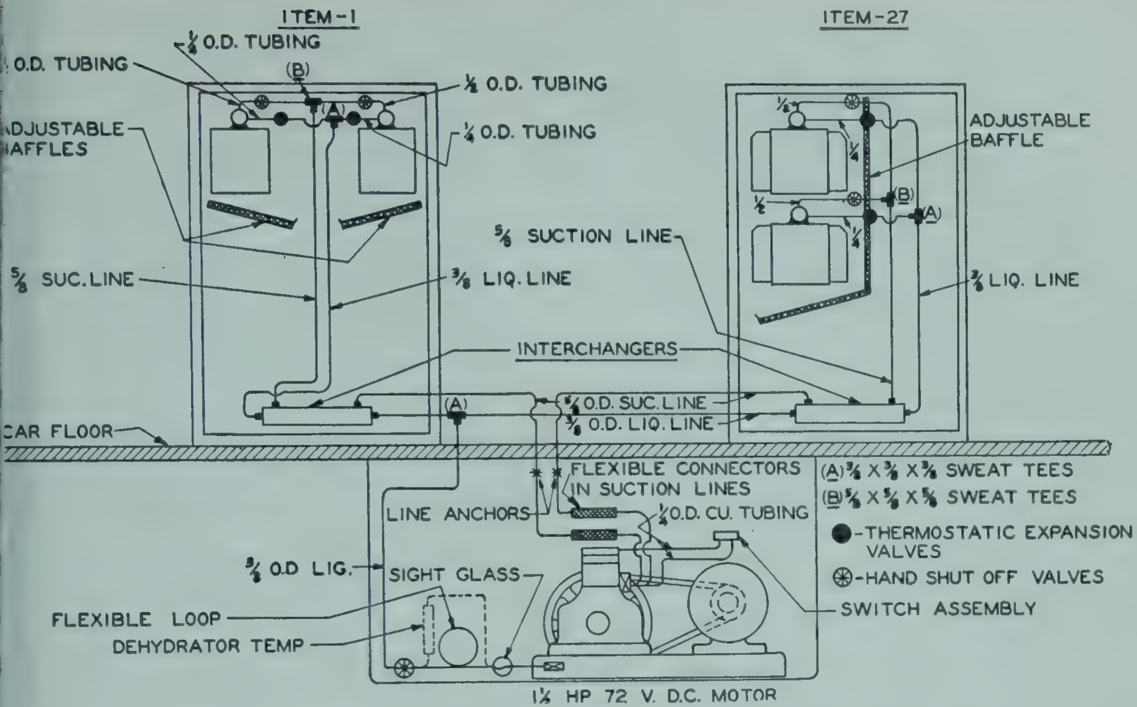


Fig. 5. Typical Lounge Car Installation with Direct Expansion Ice Freezing Coils and Under-Car Air Cooler Condensing Unit.

frequencies 1500 per second or above. Other vibrations from the condensing unit would also be of high frequency.

7. Wherever possible a 10% allowance in the condensing unit capacity for the effects of dirt accumulation on the condenser is recommended.
8. Adequate ventilation and air circulation for condensers is imperative. The following ventilation will assure proper operation:

Condensing Unit Motor Size	*Ventilation CFM (Approx.)*
⅓ hp	315
½ hp	450
¾ hp	550
1.0 hp	650
1½ hp	750

9. The amount of heat given up to the air stream by the condensing unit depends upon these factors: air temperature to the condenser, suction and discharge pressure at the condensing unit, speed of the compressor, and the operating time of the condensing unit. Any attempt to show the amount of heat dissipation for all possible combinations of these conditions is out of the question. Listed below is the approximate heat in "Btu's per watt input to the motor" given up to the air stream over the condensing unit.

Refrigerant Lines

1. Soft tinned copper tubing is satisfactory for all refrigerant lines unless otherwise specified.
2. Wherever possible sweat fittings shall

Application	*Fixture Temp °F*	*Approx. "Freon-12" Suction Pressure*	*Btu/Motor Watt 70 F**	*90 F**	*110 F**
Water cooling	45–50	28 lb	10.5	9.1	8.3
Forced Air Evap.	36–48	22 lb	9.7	8.9	8.0
Gravity Finned Evap.	36–48	17 lb	9.0	8.6	7.7
Ice Making Evap.	36–48	11 lb	8.1	8.2	7.1
Plate Type Low Temp	0–15	3 lb	7.6	6.6	6.0

* Air temperature to condensing unit.

be used and the joints soldered with 95-5 solder.

3. All refrigerant lines should be insulated with ¼ in. minimum wall thickness insulation to resist abrasion and other damage.
4. All tubing should be securely mounted and anchored so that it will be free from strains and vibration.
5. Refrigerant lines should be located inside the car, eliminating all unnecessary traps. Where unusual circumstances make it imperative that the lines be run beneath the car, provisions must be made for insulating the suction line from becoming lower than 50 F in winter or higher than 120 F in temperature in summer. This insulation also acts as protection from flying ballast, etc.
6. For multiplexed installations (2 or more fixtures on one condensing unit), hand shut-off valves are recommended for the liquid and suction lines of each fixture. See **Figs. 4** and **5.**

   Where all fixtures for a given system are located near the condensing unit, the shut-off valves may be assembled into common manifolds (one for the liquid and one for the suction line) at the condensing unit.

   If the fixtures are scattered with long runs of tubing to the condensing unit, it may be advantageous to locate the shut-off valves at the fixtures.
7. In lieu of interchangers or drier tubing for the small fixtures, soldering of the liquid and suction lines together for a minimum length of 6 ft will give satisfactory operation in most instances.

Electrical Equipment

1. All DC electrical equipment will be designed for use with voltage limitations at the motor terminals as follows:

	Rated Voltage	*Maximum Voltage*	*Minimum Voltage*
Lead Cells	36	40	18
	72	80	36
	126	140	63
Edison Cells	36	45	18
	72	90	36
	126	158	63

2. For the AC electrical equipment the frequency shall be held to 60 cycles plus or minus two cycles per second. Voltage variations shall be limited to plus or minus 10% of the nameplate voltage, in accordance with AIEE and NEMA standards for such motors.
3. The electrical equipment for each system shall include the following items:
   a. An overload protector for each condensing unit motor. For DC systems, the protector will be assembled in the control box along with certain other electrical equipment. For AC systems, the protector will be included with the line starter. It is imperative that the protector in all instances be located in the condensing unit compartment near the condensing unit, as it is designed for proper protection only when exposed to the same ambient temperature as the motor. All overload protectors will require manual resetting.
   b. For DC systems only, a low voltage relay for each condensing unit when protection is necessary against minimum voltages below those shown in item 1 above.
   c. A line contactor for each DC condensing unit, and a 3-pole starter (complete with two overload heaters) for each AC condensing unit.
   d. A 3-position safety switch for each condensing unit for use when servicing condensing unit.

For DC systems the pressure control switches, overload protector and 3-position safety switch should be assembled into a common dustproof and splashproof box. For AC systems only the pressure control switches and 3-position safety switch are assembled together in a box of the same type but of smaller dimensions.

Test Procedure for Dining Car Refrigeration

As a result of experience gained in the past, the following test procedure is suggested to furnish car builders and railroads with a definite sequence of tests that will assure proper and efficient operation of the equipment.

Prior to the start of the tests, it is assumed that the system has been evacuated,

[a]ll lines purged and leak-tested, required [a]mounts of oil and refrigerant added, high [a]nd low pressure gauges installed (where [th]ey are not permanent), and electrical [ci]rcuits checked and proper heater elements [in]stalled. (In low pressure or thermostat [s]witch, if direct current; and in contactor, [if] alternating current.)

1. Check all tubing for proper insulation, hangers, clamps and clearance through bulkheads. See that all lines to condensing units are equipped with flexible connectors (on ½ in. and ⅝ in. tubing), or loops on the smaller size tubing including ⅜ in. OD to eliminate vibration and line breakage. Check condensing unit mountings and accessibility of hand shut-off valves.
2. Install dehydrator and leave in line throughout period of test.
3. Turn compressor over a few times by hand and check belt tension.
4. Check pulley size. (See manufacturer's material list for proper pulleys.)
5. Open liquid line valve at receiver, suction and discharge valves at compressor and check to see that all hand shut-off valves are open.
6. Hold safety switch on "hand" position and run condensing unit for approximately two minutes. Check fan and air flow through condenser and compressor flywheel for correct rotation.
7. Place switch on "auto" position and start condensing unit.
8. Set switches in accordance with manufacturers recommendation.
9. Check oil level in crankcase and refrigerant in system. Add refrigerant if required. (Liquid like sight glass must show a solid column of liquid.) Keep oil level above bottom of crank case sight glass. This should show ½ of glass after pull down (6 to 10 oz on smaller units).
10. Place recording thermometers in various refrigerated fixtures, and attach high-low pressure recording instrument to compressor. Date the charts and keep log of operating data. Give car name or number, also railroad.
11. Shut off condensing unit, allow suction pressure to build up and recheck for leaks.
12. Restart condensing unit and check expansion and control valve settings. (Use all the cooling unit surface but do not allow suction line to frost back.)
13. Allow unit to cycle and reset pressure switch if necessary to give proper fixture temperature.
14. Adjust baffles where adjustable baffles are used, such as in refrigerators using ice-makers as cooling units. Fill ice trays with water and check freezing time.
15. Operate the system for approximately 24 hr after all adjustments have been made. Test high side for leaks, then shut off system and allow the suction pressure to rise to 45 lb and test the suction side for leaks.
16. Again run the condensing unit for approximately 3 hr; recheck for frost backs, oil level, refrigerant supply and fixture temperatures.
17. Remove gauges, (if temporary) and set shut-off valves for proper operation of switch. Make final leak test after all valve caps are replaced.
18. If car is to go into immediate service, unit will be left operating or in operating condition with switch in "off" position. If car will go to yards for a number of days the railroad may wish system pumped down. This is to be at the discretion of railroad inspector. Railroad inspector is to be notified that after car has been in operation approximately one week, to remove dehydrator and install filter if not already a part of the system. Tag each pressure switch assembly, showing the final pressure settings on the low pressure switch.
19. All tests shall be made in hot room where an ambient temperature of at least 80 F exists. Inside car temperatures shall be in the range 75 F to 80 F. Lacking the facilities of a hot room, some other means must be devised to produce the ambient temperature of 80 F as this is the minimum at which the test should be made.

If you searched this chapter for something which was not found in it, please let the editors know.

SECTION V

LOW TEMPERATURE APPLICATIONS

Ludwig Adams, Associate Editor. Born 8/12/16 in New York, N. Y. Educated at New York University, 1936; graduate study at Rensselaer Polytechnic Institute, Carnegie Inst. of Technology, Pennsylvania State College, and University of Pittsburgh.

Formerly with the Pittsburgh Des Moines Companies, 1937–42, 1946 to date; National Advisory Committee on Aeronautics, 1942; Mellon Institute, 1942–46; University of Pittsburgh, Instructor in Physics, 1945.

Author of the Mollier Diagram for Dry Air; articles in *Refrig. Eng., Petroleum Refiner, Chem. and Eng. News* and Trans. Am. Inst. Chem. Engrs.

Members, Amer. Soc. of Refrig. Engrs.—Abstractor; Chairman, Committee D-5, 1946; Committee A-14 (Ultra Low Temperature Application and Research), 1947–48; Member of Program Committee, 1948; Secretary, ASRE Pittsburgh Section, 1949–50; A.S.C.E.; A.W.S.; A.P.S.; A.A.A.S.; A.C.C.; Registered professional engineer, Pennsylvania and Ohio.

At present, Research Coordinator, Pittsburgh-Des Moines Companies, Pittsburgh, Pa.

46. THE PREPARATION OF BLOOD PLASMA

THE following three premises seem generally acceptable: (1) Blood plasma is used with satisfactory results in a large number of clinical conditions; (2) the effect of plasma depends on the action of several elements contained therein; (3) these elements are variously affected by the manner of preservation of the plasma.

It has been shown that all the elements of citrated plasma cannot be satisfactorily preserved in the liquid state, at any temperature, for periods longer than a few days.[13] In addition to the loss of valuable elements, such as prothrombin and complement, plasma in the liquid state may be rendered unsafe by the comparative ease of bacterial contamination and the tendency of certain proteins, such as fibrinogen, to flocculate. Bacterial growth from a minimal chance contamination, not always readily detected by bacteriological control, tends to the development of harmful pyrogenic substances. Flocculation causes danger of embolism unless filtration is resorted to. When the flocculation is maximal, such filtration may prove a troublesome process.

While it is true that the colloidal osmotic properties of plasma are retained in liquid plasma, it is desirable to resort, whenever possible, to better and safer methods of plasma preservation. Deterioration of plasma, with loss of labile components, as well as bacterial contaminations and flocculation, may be effectively prevented by rapid separation of plasma from freshly collected blood, followed by prompt fixation of plasma by freezing. Plasma may then be stored in the frozen state or, if it is considered desirable, dried from the frozen state.

Proper restoration of frozen or dried plasma results in a liquid free from flocculi. It must be noted, however, that while plasma properly restored from the frozen state is practically indistinguishable from the original material, plasma restored from the dried state is turbid. This turbidity, however, does not apparently cause any untoward effects.

Details of preparation of pooled citrated plasma and of proper regeneration of plasma from the dried and frozen state have been given elsewhere.[1,15,18] The present paper deals with: (1) General considerations on freezing of plasma and preservation in the frozen state; (2) specifications for plasma freezing and storage cabinets; (3) drying of plasma from the frozen state; (4) hospital needs and recommendations.

General Considerations

When plasma is supercooled previous to freezing, at temperatures below 0 C (32 F), flocculation, or at least increase in turbidity, may occur if the period of supercooling is protracted. This is particularly true when the temperature falls below 6 C (42.8 F). It is also important to note that, even after the largest portion of the plasma has apparently frozen, it takes a considerable length of time for complete freezing. If this period of time is too long, the stability of certain proteins may be affected, so that flocculation occurs when the plasma is returned to the liquid state. In other words, in specifying requirements for freezing of plasma, we must be concerned not only with the temperature but also the heat capacity of the apparatus. Theoretically, to freeze 300 cc of plasma and cool it to −4 F (−20 C) requires approximately 134 Btu (38.4 kilocalories) when the original temperature is 77 F (25 C).

MAX M. STRUMIA, Author Chapter 46. Born 9/23/96, in Turin, Italy. Educated at the University of Turin, MD, 1920; University of Pennsylvania, Dr.Sc., 1924.

Author of Atlas of Hematology; co-author of Blood and Plasma Transfusions, etc.; author of Chapter 42, 1946 Applications Volume, ASRE Data Books; numerous articles on medical subjects.

Member, American College of Physicians; Amer. Society of Clinical Pathologists; Amer. College of Pathology; Amer. College of Pathology and Bacteriology; Philadelphia College of Physicians; Amer. Medical Assn.

At present, Director, Laboratory Clinical Pathology, Bryn Mawr Hospital; Associate Professor, Graduate School of Medicine, University of Pennsylvania.

However, it must be remembered that glass is a very poor conductor, and that this greatly interferes with the heat exchange between plasma and cooling medium. Consequently, in addition to the absolute temperature of the cabinet, and the capacity of the compressor already mentioned, the medium of heat dispersion between the evaporator coils and the surface of the bottle is a very important factor in determining the time of freezing.

Let us consider a typical temperature curve when 300 cc of plasma is frozen in a standard 400 cc bottle, **Fig. 1.** This curve was obtained by thermometric readings while the bottle of plasma was placed horizontally in a copper half-shell, in contact with the metal walls of the freezing cabinet. The temperature of the cabinet (air) was −21 to −22 C (−5.8 to −7.6 F). To facilitate the observation of the temperature and progress of freezing, the freezing chamber was closed with a heavy plate glass.

Initiation of freezing, under the experimental conditions, required from 60 to 75 min. The period of supercooling, between 32 to 21 F (0 to −6 C) should not be prolonged. It is essential to produce initial freezing as soon as possible, as the temperature will remain at about 0.56 C (33 F) as long as the bulk of the plasma is frozen. Under the experimental conditions this requires about 3.5 hr. However, when the temperature of plasma begins to drop below 30.2 F (−1 C), the material is as yet not completely solid. Complete solidification takes place when the temperature drops to 21 to 23 F (−5 to −6 C), and this requires an additional 75 min. The time from the beginning of cooling to apparent complete solidification should not exceed 6 hr.

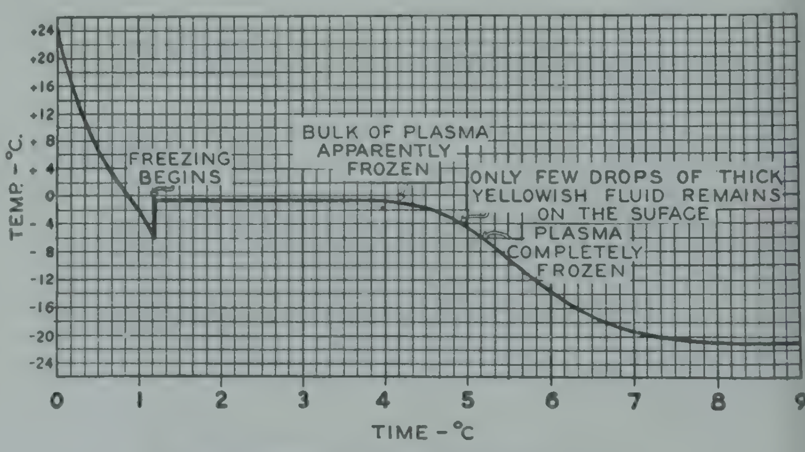


Fig. 1. Typical Plasma Freezing Curve.

When complete freezing of plasma occurs in approximately 6 hr or less, **optimal preservation of plasma is assured.** It takes another 3.5 hr to cool the material to −4 F (−20 C). It is during this period of time that bottles made of poor quality glass, improperly filled or not properly inclined, will break because of expansion of the frozen mass of plasma. Placing the bottles on a slant during freezing in such a fashion as to obtain the largest possible surface of fluid, without entirely filling the neck, effectively prevents breakage.[1a]

Quick freezing beyond the limits just mentioned, does not in any way improve the practical value of plasma. This has been proved by determinations of the hydrogen ion concentration, prothrombin complement, and turbidity on a number of specimens of plasma frozen at temperatures ranging from −10 to −95 F (−12 to −70 C).

In general, it has been the experience that many ice-cream cabinets, frosted foods, cabinets and similar apparatus available for commercial use fall short of the minimum requirements for plasma freezing and storage cabinets. The painstaking effort in the processing of plasma should be carried on through the preservation technique, and due care should be used in selection of the equipment. When ice-cream or similar cabinets have been used, the liquid plasma is actually frozen, rather by the frozen plasma as a refrigerating agent than by mechanical means. Under these conditions, the temperature of

the frozen plasma may rise to near the melting point, or actually melt in spots (slushing), with resulting deterioration.

Specifications for Freezing and Storage Cabinets

In the selection of freezing equipment, consideration must be given not only to the proper freezing time but also to the quantity of plasma to be frozen at any given time, that is, the size of each pool of plasma, and in larger laboratories, the number of pools ready for freezing at any one time. Consideration should be given to:

Compressor and evaporator
Means of heat removal
Insulation
Safety devices
General construction
Performance.

These points will be briefly discussed.

Compressor and evaporator. The capacity of the compressor and evaporator should be such that freezing of the specified quantity of plasma contained in glass bottles will take place within 6 hr. Standard commercial condensing units designed for low temperature operation and with the required capacity have been found entirely satisfactory. Installation of condensing units should be made in such a manner that adjustments and repairs can be easily made. Ample provision should be made for ventilation of the air-cooled condensing units.

Low sides (evaporators) of the semi-flooded steel plate type or tanks of copper with continuous copper tubing (or if joined, joints to be silver soldered) soldered to the outside have given satisfactory results. Where freezing and storage compartments are joined in one cabinet, two expansion valves must be used with necessary check valves. Manually operated shut-off valves should be installed in order to permit independent operation of either compartment and defrosting when required. The condensing unit should be controlled through electrical switches which will serve to stop and start the unit and also to select either constant unit operation for lowest temperature or intermittent operation for controlled temperature within the limits of the automatic temperature control.

Means of heat dispersion removal. If a bottle of plasma is placed in a freezing cabinet with improper contact with the refrigerated metal walls so that the heat interchange is carried out mainly by still dry air, the time of freezing when the cabinet is loaded to capacity is generally unduly prolonged.

There are several methods which may be employed to improve the heat interchange between the plasma and the cooling surfaces. An excellent method consists in rotating the bottle containing the plasma while submerged in a circulating cooled brine. This method, however, offers some mechanical difficulties which render it impractical. Of the various methods tried, three have proved satisfactory and economical:

1. Improving the heat transfer by **conduction.** This is efficiently accomplished in an evaporator where the bottles have contact with refrigerant-carrying surfaces over as large a surface as possible. In this type of evaporator the bottles are placed in a slanted position whereby the expansion surface of the plasma within the bottles is increased during the freezing period. No mechanical devices are required for holding the bottles in this preferred position. Bottle breakage during the freezing is eliminated or reduced to a minimum.

2. Increasing the heat transfer by **convection.** This is accomplished by a small air fan, operated by a fractional electric motor, both of proper size and capacity to meet the performance specified. The bottles are held in the suggested position, as previously outlined, by a rack. The fan should be controlled by a manually operated and an automatic switch, installed in such a manner that the current to the fan motor is shut off when the lid is opened. This will eliminate loss of cooled air and safeguard against injury to the technician by the fan.

3. By **both conduction and convection.** This is accomplished by maintaining the bottles in the proper slanted position by means of a metal rack, which holds at least one side of the bottles in contact with the refrigerant-carrying walls. Convection

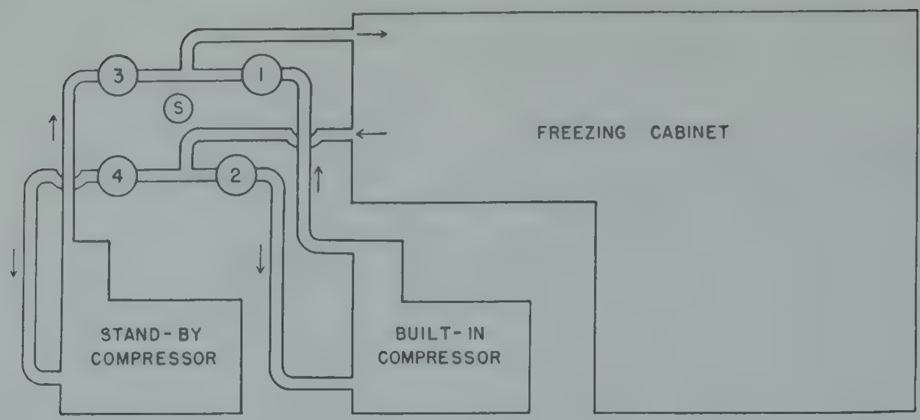


Fig. 2. Freezing Cabinet with Manually Controlled Stand-by Compressor.

is assured by a small air fan, as outlined in (2) above.

Care should be taken for the lubrication of the drive shaft of the fan so that it will not be affected by the low temperature and will assure trouble-free operation.

It must also be mentioned that freezing can be improved by partly filling the freezing compartment with a fluid such as 75 percent alcohol. When this fluid has been cooled to the temperature of the evaporator, the bottles are partly immersed and maintained in the proper slanted position.

Insulation. The importance of the insulating material and its thickness cannot be over-emphasized. Insulation should be 4 in. of solid corkboard, or equivalent on sides and bottom of cabinets and 2½ in. on top and access doors. Insulating material subject to settling is not acceptable. The proper application of the insulating materials is equally important, in order to make the cabinets as nearly moisture-proof as possible. The insulating material should be laid in a moisture-proof emulsion with all joints broken, and on the outside layer a paper should be applied; also insulating material should be contained in a moisture-proof metal housing. Expansion valves must be so protected as to eliminate all frost accumulation and permit ready access for adjustments.

Safety devices. A thermostatically operated alarm system with a buzzer and a warning light should be an integral part of plasma storage cabinet. This alarm system should operate automatically when the temperature of the storage cabinet has risen to approximately 5 F (−15 C). It is necessary that separate electrical circuit be provided for the alarm system or that the alarm system be operated by dry cell batteries. A switch arrangement should be provided which will permit silencing of the audible signal without affecting the visual signal. Either or both the visual and audible signals may be remote.

A satisfactory arrangement for larger institutions and for centers serving several smaller hospitals is to have a freezing cabinet capable of a rapid turnover, and a separate storage cabinet or cabinets of suitable capacity. This allows easy expansion of the storage capacity with minimum expense.

The installation of a complete automatic standby system in the storage cabinets, giving double protection against mechanical failure, is also recommended. Basically this standby system will go into operation when the temperature has risen to the point when the alarm system functions, 5 F (−15 C).

Simpler, and in practice equally satisfactory, is the addition of a stand-by unit not automatically controlled. Manually controlled valves should be provided, as well as separate expansion valves. A diagram of a satisfactory arrangement is given schematically in **Fig. 2.**

General construction. Rigidity of the cabinets is essential to proper installation of insulating material and for the required support of the condensing unit. Cabinets should be made self-contained and be ready for operation when delivered by

merely plugging in connection to electric circuit.

Inside and outside finish of the cabinets should be rust-resistant either by choice of proper material or by adequate treatment of the surface. These finishes should permit easy cleaning for strict sanitation. The safety device and control switches should be located so that they are clearly visible and easily accessible with proper instruction plates. All seams in the interior compartments should be soldered or welded so as to be water-proof. It is desirable to have round corners to facilitate cleaning.

The interior of low temperature compartments should be accessible through top lids or hinged covers. Lids or doors are provided with suitable gaskets to reduce heat losses and frosting. Outer and interior metal linings must be separated by breaker strips or suitable material, such as bakelite or micarta placed around the edges of the cabinet opening or openings.

Freezing and storage of plasma should be segregated either by using individual cabinets or a cabinet where the compartments are separated by insulation as previously outlined.

Performance. To insure proper workmanship and satisfactory performance, the refrigerator should be built by a manufacturer having experience in the manufacture of low temperature freezing refrigerators designed for use with electrically operated condensing units. The refrigerator should reduce the temperature of the specified quantity of plasma in lots of about 300 cc in suitable glass containers from 77 F (25 C) so that initial freezing will occur within 90 min.

Complete freezing should take place in less than 6 hr from the initiation of cooling, while a temperature of −4 F (−20 C) is maintained in the empty storage cabinets. The compressor should be of such capacity that, with the freezing compartment in operation with a full load of plasma, the temperature of the plasma in the storage compartment will not rise above −4 F (−20 C).

The insulation and the heat capacity of the cabinet should be such that when the storage compartment is filled to half capacity with plasma frozen to −4 F (−20 C), the temperature rise to the melting point will not occur in less than 24 hr. Thus in case of mechanical breakdown of refrigerating machinery or temporary power failure, repairs can generally be made before thawing and deterioration of stored plasma occurs. The refrigerator should be capable of maintaining in the storage cabinet an average maximum temperature of −4 F (−20 C) with a full load.

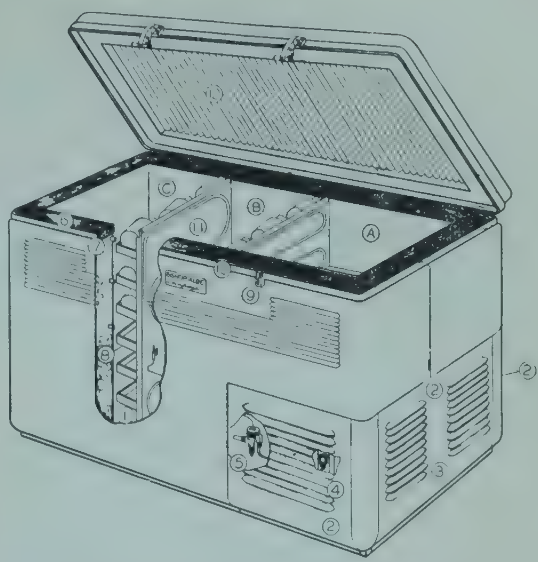


Fig. 3. A Very Satisfactory Commercially Available Unit for Freezing and Storing Plasma.

Typical Cabinet for Freezing of Plasma and Preservation in Frozen State:* The unit shown in **Fig. 3** is especially designed and constructed for blood plasma storage and freezing.** The unit is built in 14 cu ft storage capacity, as shown in the drawing, or can be had in 18 cu ft storage capacity where additional low-temperature storage is required.

The interiors of the cabinets are aluminum, the 14 cu ft cabinet has three (3) compartments, and the 18 cu ft cabinet has four compartments. The aluminum liner is a refrigerated cooling surface, and the plates that separate the interior into compartments are also refrigerated cooling coils. Aluminum brackets are attached to the divider cooling plates to accommodate

* Reprinted with permission of the Publishers from "Blood and Plasma Transfusions" by Dr. Max M. Strumia and Dr. John J. McGraw, Jr., F. A. Davis Company, Philadelphia, 1949.

** This apparatus is built by the Bishop Co., and distributed by The Aloe Co., St. Louis, Mo.

the standard 400 cc bottles. These bottles lie against the cooling surface for quick initial freezing by conduction, and the brackets slope to keep the bottles inclined while freezing at a 12-degree angle.

The exterior of the cabinets are 18-8 stainless steel. The one-piece, counterbalanced lid is constructed of a durable plastic so that there can be no rusting or deterioration on the cabinet exterior. All corners are rounded for ease in cleaning.

Other features of the freezer, which can be seen in **Fig. 3**, are as follows:

1. Special aluminum bottle racks on two cooling plates, 54.6 cm ($21\frac{1}{2}$ inches) wide and 68.6 cm. (27 inches) deep, holding a total of thirty-six standard 400 cc bottles. They can be moved to either of the compartments for storage after freezing.
2. Three snap-lock panels with ventilation grilles, easily removable for access to condensing-unit compartment.
3. Condensing unit or hermetically sealed construction with no belts nor motor oiling, for 1 phase, 60 cycle, 110 volt electric circuit. Furnished with $\frac{1}{4}$ horse power motor for 14 cu ft, size and $\frac{1}{3}$ hp motor for 18 cu ft size.
4. Thermostatic control with dial temperature index. Should be set at -20 to -25 C for normal operation, then reset to 30 C for rapid freezing of plasma.
5. Thermostatic expansion valve, which automatically controls refrigerant supply to cooling coils for any thermostat temperature setting.
6. Solid cushion seal, which assures perfect cover seal, avoids freezing of lid, and prevents vapor transfer and sweating difficulty.
7. Stainless steel exterior, easy to clean.
8. Foamed plastic insulation, has K Factor of .19, 50 percent more efficient than cork.
9. Positive closing cover clasps, which are set for complete closing and effective sealing to prevent cooling loss. Clasps may be padlocked.
10. Plastic breaker strip, connected to inner and outer liner by a plastic-metal weld process. Insulation in cabinet and lid is thus hermetically sealed and pressure tested, assures positive protection against moisture-vapor transfer to the insulation, and prevents ice formation therein.
11. Aluminum cooling coils, acting as di- vider plates, give additional freezin capacity and put the refrigerant sur face in the center of the cabinet wher needed for quick freezing.
12. Plastic lid, heavily insulated, durable noncorrosive, and easy to clean. Cali brated spring hinges on the rear of th lid give perfect ease of operation an hold lid in an open position.

DIMENSIONS

	14 Cu Ft Freezer Inches	18 Cu Ft Freezer Inches
Exterior length......	58	69
Exterior width......	$29\frac{1}{2}$	$29\frac{1}{2}$
Exterior height......	$35\frac{3}{4}$	$35\frac{3}{4}$
Interior length......	50	61
Interior width......	$21\frac{1}{2}$	$21\frac{1}{2}$
Interior height......	29	29

Size of Compartment in 14 Cu Ft Freezer

	Inches
A.........	$19\frac{1}{2} \times 21\frac{1}{2} \times 12\frac{5}{16}$
B.........	$15\frac{1}{4} \times 21\frac{1}{2} \times 29$
C.........	$15\frac{1}{4} \times 21\frac{1}{2} \times 29$
D.........	None

Size of Compartment in 18 Cu Ft Freezer

	Inches
A.........	$19\frac{1}{2} \times 21\frac{1}{2} \times 12\frac{5}{16}$
B.........	$13\frac{27}{32} \times 21\frac{1}{2} \times 29$
C.........	$13\frac{27}{32} \times 21\frac{1}{2} \times 29$
D.........	$13\frac{27}{32} \times 21\frac{1}{2} \times 29$

Temperature curves obtained by mean of a multiple-lead recording pyrometer wit an experimental cabinet are shown. In **Fig 4** the proper freezing is obtained, with th bottles in contact with the refrigerate walls. **Fig. 5** shows improper freezing, wher the bottles are not in contact with th freezing walls. **Fig. 6** shows the increase speed of freezing by circulating the air **Fig. 7** shows that this can be still furthe speeded by contact with the cold surfaces

Drying of Plasma from the Frozen State

In order to evaluate properly the construction and performance of apparatus fo drying of plasma from the frozen state, it i necessary to review the general basic prin-

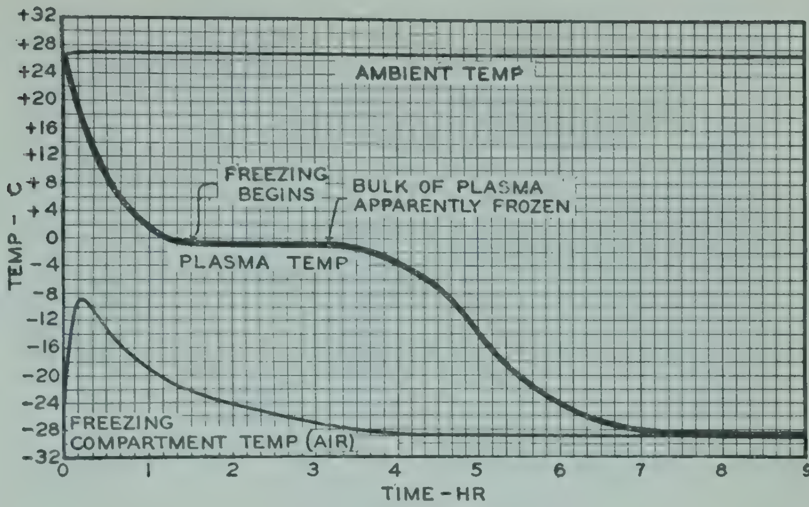


Fig. 4. Freezing Curve —Without Aid of Air Circulation Bottles in Contact with Refrigerating Surfaces.

ciples of drying biologic substances. The Bordas and d'Arsonval apparatus[3-b] as reconstructed by the author demonstrates these basic principles in a simple form **(Fig. 8).** It consists of two glass flasks connected by a T-tube. One flask (A) contains a thin layer of material to be dried. The other flask (B) is the condenser. The T-tube is connected to a vacuum pump by means of a rubber tube (C), which may be closed by a stout pinch clamp. The glass tube connecting the two flasks must be of sufficient size to allow free passage of water vapor from A to B. Flask A is immersed in water kept at 59 F (15 C), and Flask B, acting as condenser, is cooled by immersion in carbon dioxide ice-alcohol mixture, maintaining a temperature of about −158 F (−70 C).

Containers A and B are stout-walled Erlenmeyer flasks of about 500 cc capacity. Under these conditions, when 30 cc of plasma is introduced into flask A, "snap" freezing, from the heat loss due to rapid evaporation, occurs in about five minutes after starting of the vacuum pump; thereafter, drying proceeds by sublimation of water from the frozen state. The water vapor is condensed on the cold walls of flask B as fast as it is formed; thus it is not allowed to mix with the oil of the pump, which would rapidly reduce the efficiency of the pump. The dried plasma thus obtained appears in the form of irregular scales, has a residual moisture of less than 1 percent, and is readily soluble.

Practically all of the various types of apparatus in general use for drying under

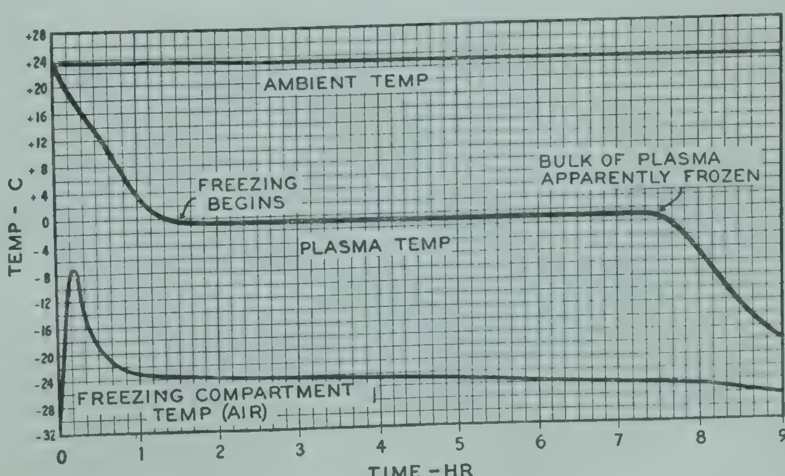


Fig. 5. Freezing Curve—Without Aid of Air Circulation Bottles not in Contact with Refrigerating Surfaces.

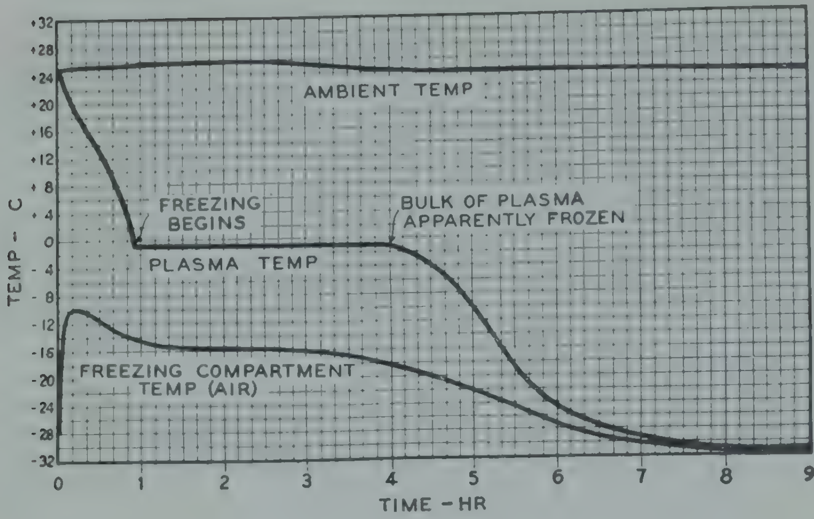


Fig. 6. Freezing Curve—With Aid of Air Circulation Bottles not in Contact with Refrigerating Surfaces.

vacuum are based upon variations in the method of condensing the water vapor. In the original apparatus used by Bordas and d'Arsonval, liquid air or carbon dioxide snow-acetone was used as refrigerating agent.

Vansteenberghe[3-4] used sulfuric acid to absorb the water vapor instead of low temperature; Reichel[5] and Flosdorf and Mudd[6] used an apparatus similar to that of Bordas and d'Arsonval and CO_2 ice as the refrigerating agent for the "Lyophile" process; later Flosdorf and Mudd[7] returned to the use of a chemical dehydrating agent and employed calcium sulfate in their "cryochem process": Hill and Pfeiffer[8] used silica gel in their "Adtevac" process.

Elser[3f] was the first to report the use of coils refrigerated by the expansion of compressed Freon-12 gas for condensation of water vapor. In actual operation, −30 to −33 F (−34 to −36 C) were the lowest temperatures attained. Elser pointed out that the loss in efficiency from the change of the condenser temperature from −95 to −25 F (−70 to −32 C) was relatively slight, roughly 5 percent.

The failure of the mechanical refrigeration system of Elser has generally been laid to the too small differential in temperature between the substance being dried and the condensing surface. This is not confirmed by the author's findings, since satisfactory drying with a residual moisture of less than 1 per cent has been obtained with a maximal differential temperature of only 149 F (65 C).

We have already pointed out that the

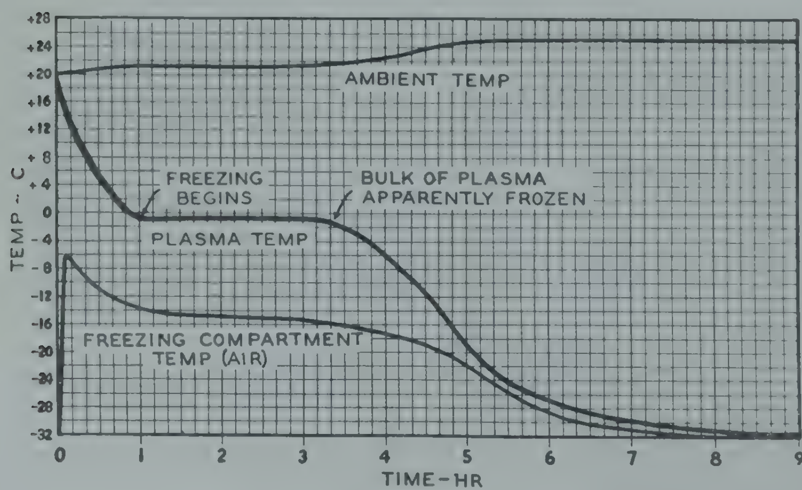
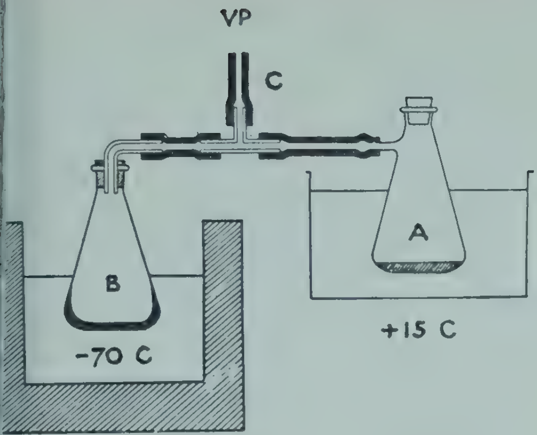


Fig. 7. Freezing Curve—With Aid of Air Circulation Bottles in Contact with Refrigerating Surfaces.



ig. 8. Bordas and d'Arsonval Apparatus for Drying of Easily Alterable Substances.

a. Receptacle Containing Material to be Dried
b. Receptacle Acting as Condenser
c. Connection to Vacuum Pump

emperature of prefreezing is not critical within the experimental limits. With the apparatus developed by the author, prefreezing and drying are carried out at much higher, and therefore much more convenient and economical temperatures, than generally employed, without essential loss of quality of the material being dried. Greaves and Adair[9] likewise found that the lowering of the condenser temperatures lowers the temperatures of the frozen material being dried to a very slight extent only. They successfully employed methyl chloride as the refrigerating agent, and obtained temperatures of −60 to −44 F (−52 to −42 C).

Greaves and Adair state that with temperatures of −50 F (−45 C), the percentage of water remaining at the end of desiccation is much less than when higher temperatures are employed. We have found that with the water jacket of the drying chamber at 95 to 97 F (35 to 36 C), and temperatures of condensation of −22 to −31 F (−30 to −35 C), the residual moisture of the resulting material is constantly less than 1 percent.

The method employed for the determination of the residual moisture is that described by the National Institution of Health, i.e., drying of the material in high vacuum over phosphorus pentoxide to constant weight. The great advantages in the employment of relatively high temperatures of water vapor condensation are, essentially, simplicity of operation and economy, since the heat neutralizing capacity of a compressor falls rapidly with the lowering of the temperature of condensation.

There are two methods of drying under vacuum which do not employ a condenser. One of these, the "Desivac" machine,[10] allows the water vapor to enter the vacuum pump and constantly removes the water from the oil by means of a high-speed centrifuge. The high cost of this apparatus and the relatively long drying time make its operation uneconomical. Another method produces a vacuum by means of multiple steam jets, in which case the water vapor escapes with the steam, thus eliminating the need for a condenser. This method is particularly suited to large quantity production on a commercial scale.[11]

With the possible exception of the method of Greaves and Adair, all of the above-mentioned methods require large and expensive apparatus to dry enough plasma to consider the process practical. In addition, the use of chemical desiccants requires redrying of the desiccant each time it is used, an operation entailing considerable time and expense.

An apparatus for the drying of plasma from the frozen state by low temperature water vapor condensation in vacuo, previously described by the author, was based on the principles laid down by Bordas and d'Arsonval and on the work of Shackell,[3–d] and Rogers.[3–e] In the construction of the drying chamber, advantage was taken, for proper heat distribution to the material being dried, of copper split cylinders or shells enveloping each bottle. These shells, properly fastened together, formed also a desirable method of handling the bottles during the loading of the drying chamber, making the operation easy and rapid. In the construction of the condenser, we took advantage of details of construction pointed out by Reichel[5] and by Flosdorf and Mudd.[6] This condenser was externally cooled by the use of alcohol-carbon dioxide ice mixture.

Routine use of this apparatus pointed out that while the drying chamber proved

fairly satisfactory, the condenser was rather crude in design and expensive in operation, particularly because of the cost of carbon dioxide ice and the necessity for almost continuous supervision. The presence of a secondary condenser made the apparatus difficult to handle and proper insulation an almost impossible task, with the result that much of the low temperature produced by the carbon dioxide ice was wasted. The time of drying was three days or more.

Attempts to eliminate the use of dry ice by cooling the condenser by the use of a low-temperature, two-stage (cascade) compressor using Freon-12 (or propane) and ethane as refrigerants, and of a circulating brine system giving a condensing temperature of about −75 F (−60 C), have given an apparatus proving too bulky, expensive, and unreliable. It is now questioned whether such low temperatures are required.

Various types of apparatus described for the desiccation of plasma from the frozen state have been either too small for practical use or too expensive, if large enough to serve the purpose. Some types, although inexpensive to purchase, have proved a financial burden because of the operating expense and the need of much technical supervision. Most of these systems have been recently critically reviewed by Harkins.[2]

Of the methods in use, desiccation from the frozen state in the final container is preferred, because this method provides for maximal preservation of all elements of the plasma, maximum solubility, minimal opportunity for contamination during the process of drying, and regeneration with 0.1 per cent citric acid prior to use. The pH of plasma dried from the frozen state and restored with distilled water varies from 8.2 to 9.3. The same material regenerated with 0.1 per cent citric acid will have a pH varying from 7.4 to 7.8.[15]

The use of low temperatures for the condensation of the water vapor removed from the frozen plasma is preferred because it is efficient and relatively inexpensive. In the apparatus to be described here, the same source of low temperature is used for both prefreezing of the plasma in shell form and for water vapor condensation during the process of drying. The source of low temperatures is obtained by expansion of compressed Freon-12 gas in evaporator coils or plates. It is based on the fundamental principles employed by the early workers in this field.[3]

Several principles of design which previously have not been generally accepted or taken advantage of are as follows:

1. Temperature of freezing of plasma has little or no practical effect on the quality of the final product (in experimental range of −12 to −72 C (+10 to −100 F)).
2. Temperature at which water vapor condensation is carried out is not critical (within the experimental limits of −22 to −100 F (−30 to −72 C)), provided the rate of evaporation at any time during the operation is sufficiently rapid to avoid thawing the frozen plasma. This is readily accomplished by using a condenser possessing a condensing surface sufficiently large and by taking advantage of certain details of construction of the condensing chamber to be pointed out later.
3. The temperature of the condensing coil during the period of maximal sublimation may rise somewhat above the minimum mentioned (−22 F) without adversely affecting the process, provided that during the last few hours of the process the temperature is maintained at −30 C (−22 F) or below.
4. Temperature of the water jacket heating the plasma may be raised, during a portion of the process, to relatively high temperatures 175 F (80 C) without impairment of any of the essential qualities of the resulting product, but with considerable shortening of the time of drying, as compared with apparatus without proper thermic control.
5. The temperature of the plasma itself may be raised for a short period of time, to relatively high temperatures (122 to 176 F) without deterioration, provided that the amount of moisture

present is relatively low. This occurs in the last few hours of the process.

Several types of inexpensive standard re-gerating machines on the market are pable of producing constant tempera-res of −40 F, allowing the construction a satisfactory apparatus at a low cost.

6. The product obtained should, when regenerated with solvent, be as nearly as possible identical with the original material. The apparatus and process employed, therefore, must allow no degeneration to occur during the process of drying. The plasma obtained with the apparatus here described in all ways complies with the regulations set forth by the National Institute of Health.
7. The apparatus must be so designed and the operation so controlled as to be constant, thus insuring a uniform product. It must be remembered that drying from the frozen state may be achieved in a great many ways and with much simpler apparatus. However, mechanical controls of temperature, recording devices for temperature and pressure, and other refinements of construction play an important role in insuring a uniformly good product.

It has been pointed out that drying from the frozen state may be achieved with a simple and inexpensive apparatus.[4] Such an apparatus, however, has a limited capacity, requires much technical supervision, and is high in operating cost. The apparatus favored by the author will have a capacity large enough for the need of several hospitals, will require little attention and operate cheaply.

One such system designed by the author and manufactured by the Precision Scientific Company is contained in a single cabinet (see **Fig. 9**). It is powered by a Freon-12 compressor capable of maintaining, under maximum load, a temperature of −30 to −50 C (−22 to −58 F) in the condensing coils and of maintaining the circulating alcohol in the shelling pan at a temperature of −25 to −35 C (−13 to −31 F). The apparatus includes a shelling pan with a device to circulate cold

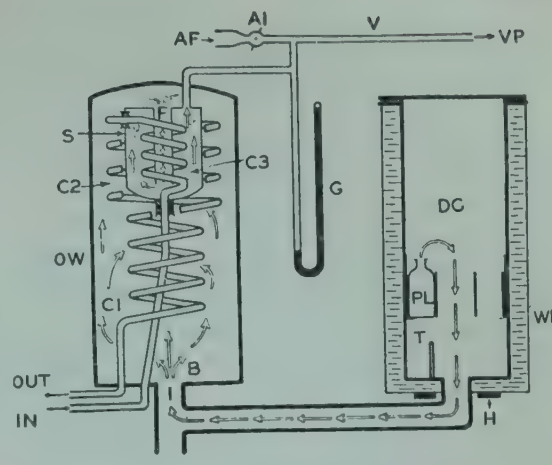


Fig. 9. Apparatus for Freezing and Drying of Plasma.

alcohol and to rotate slowly the bottles containing the plasma. Freezing of the plasma in a shell form is carried out at a relatively high temperature (−31 to −13 F) by taking advantage of rapid cooling followed by *local* snap freezing which is obtained by temporarily stopping the rotating motion. After the local snap freezing has occurred, the rotating motion is resumed. This procedure effectively prevents super-cooling as well as "mushing" of the plasma with formation of an uneven shell, which greatly interferes with proper drying.

The drying chamber and the condenser are connected by a short, thick tube and together they form a letter U. Provision is made to convey heat to the material being dried by means of an electrically heated water jacket and copper baskets. In these copper baskets, the bottles may be maintained with the mouth down, which greatly facilitates the escape of water vapor.

The condenser is of such a design that it maintains the water vapor in a prolonged contact with the condensing surfaces, thus avoiding the need for a secondary condenser. One such apparatus freezes and dries 24 units of citrated plasma of 300 cc each daily (7.2 liters) or 8760 yearly (2629 liters).

The total cost of electric energy for shell-freezing and drying is about 2 cents per unit, or less than $175 yearly. For the same operation, if carbon dioxide ice were

employed, the yearly cost of refrigeration would be about $3006, or considerably more than the entire cost of purchase of the apparatus.

For complete details of this apparatus, see *Jour. of Lab. and Clin. Med.*, vol. 28, no. 9, pp. 1140–1155, June, 1943.

Hospital Needs and Recommendations

Preservation of plasma in the **frozen state** has been recommended as the safest, most efficient, and practical method for the average hospital.[1] The establishment of "plasma banks" in which the plasma is maintained frozen will allow most institutions to meet the routine or emergency needs of the communities which they serve in almost all instances. During the war, banks of frozen plasma were established in many hospitals throughout the country in view of the increasing danger of industrial accidents associated with large scale production and the possibility of enemy action within the United States. Large stores of dried plasma were prepared for use with the Armed Forces beyond the limits of the continental United States. Conditions do exist, and further situations may arise, in which a certain amount of dried plasma is needed for civilian use.

Very few hospitals at present are in a position to offer the use of **dried plasma** for their patients, except through outright purchase of the material. This situation in effect denies the patient the opportunity of availing himself of the use of friends and relatives as volunteer donors. In a previous publication[1-b] it has been pointed out that this difficulty could be overcome if a group of hospitals would cooperate in the preparation of dried plasma. Since the preservation of plasma in the dried state is only seldom essential in the ordinary civilian practice, a single large institution could easily dry a sufficient quantity to meet the need of several others on a cooperative non-profit basis. Almost any hospital can easily maintain its own store of frozen plasma, which would be supplemented by a small amount of the dried material supplied by the drying center. Under favorable conditions, a large institution may assume the responsibility for supplying plasma in both frozen and dried states for neighboring institutions.

A plan of this nature has been operating successfully for several years in the Cincinnati General Hospital under Dr. Hoxworth.[16] The service supplies the needs of 14 hospitals with a total bed capacity of 4235.

State-wide and county-wide plans for preparation and distribution of plasma have been in successful operation for a number of years. The recent introduction of devices for the sterilization of plasma by means of ultra violet irradiation has eliminated the danger of transmission of diseases caused by viruses, particularly of homologous serum jaundice.

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If you searched this chapter for something which was not found in it, please let the editors know.

47. LOW TEMPERATURE AS APPLIED TO METALS

BECAUSE conventional heat treatment frequently has failed to develop a uniform structure in tool steels, metallurgists are now supplementing those processes with sub-zero treatment at −100 to −120 F. The first refrigerants used were liquefied gases and solid CO_2, or dry ice. Required temperatures can now be reached by mechanical means. As early as 1914, 18-8 stainless steel was refrigerated to develop spring properties for submarine use. Investigation was carried further on other alloyed steels. Tool steels have been benefited greatly from this research. Today's refrigeration processes are applicable as well to both 18-4-1 high-speed steel, the 18-4-1-4 cobalt steels, and molybdenum high-speed types and many other highly alloyed steels.

Improvement in hardness was first questioned as possibly developing such a brittle condition that tools would be almost useless. But impact specimens showed that ductility could be substantially increased when parts were tempered to working hardnesses. Steels, when first refrigerated, had a high enough hardness so that the ductility factor was somewhat impaired, and a tempering operation, therefore, was included.

If 18-4-1 high-speed steel were hardened at about 2340 F, experimentation showed that the critical point would be about −110 F. Up to this point, hardness and size increased, and magnetic qualities improved. A continuous cooling rate from the hardening temperature down to − 100 F was an important factor in attaining maximum results from this low temperature.

G. B. Berlien, Author Chapter 47. Born 1908 in Holland, Michigan. Educated at Lewis Institute, Division of Armour Institute of Technology, Chicago, and Northwestern University, Evanston, Illinois. Formerly, Chief Metallurgist, Lindberg Steel Treating Company, Chicago, Illinois.

Author of miscellaneous articles on heat treatment of steel in *Iron Age*, *Steel*, and *Metal Progress*.

Member, American Society for Metals and American Society of Tool Engineers.

At present, Partner, Industrial Steel Treating Company, Oakland, California.

High-Speed Steel

With this process all steels are first conventionally hardened. For example, high-speed steel is given one or two preheats, and then brought up to the regular hardening temperatures, either in atmosphere-controlled furnaces, reverberatory open fire or salt bath, and then quenched in oil, lead or salt, cooled in air to about 200 F, and then transferred to a refrigerating medium.

Increased cooling rates do invite failure through hardening cracks, but if the tool is introduced to the cooling medium from a sufficiently low temperature, i.e., 150 F, the danger is minimized. If the tool is fairly large, the cooling rate will be reduced because of cross section.

Tools that are quenched and allowed to remain at room temperature from 3 min to 30 hr develop a condition wherein the austenite or as-quenched condition stabilizes itself. It is then difficult to transform it by refrigeration unless lower temperatures are used.

To realize full value from this new process, the tool should be cooled directly from the quench in a **continuous cycle**, right down to −110 F. An average of −120 F will develop the greatest degree of sub-zero martensitic decomposition, or as-quenched structure breakdown.

Time cycles for cooling are usually about 6 hr. After allowing the tool to return to room temperature, it should be tempered or drawn to 1000 or 1100 F. Because double tempering is practically a requirement for good cutting tools, the cycle is repeated.

Quenching and drawing without refrigeration stabilize austenite much as when steel is allowed to stand at room temperature. Therefore refrigeration should precede both draws. Very intricate sections may require that the tool be tempered first, refrigerated after the first draw at slightly lower temperatures such as −120 to −130 F, and then retempered.

Because the percentage of loss depends

somewhat on the operation performed and the design of the tool, it can be held to a minimum. A surprisingly small quantity of tools will crack out of those properly heat treated by the sub-zero transformation method. With this type of treatment on conventional 18-4-1 high-speed steel, as much as 80 and, in some cases, 100% greater life per grind were found to be average. Because all jobs have not proved quite so successful, it cannot be claimed that this treatment will double or triple the cutting efficiency of all high-speed tools, but certainly cutting efficiency is materially improved.

By introducing a cooling cycle and another tempering operation on these tools, cutting qualities have been improved on stock cutters, where the heat treatment record has been lost or was never known. Even on stock cutters where retained austenite is very stable, the cutting qualities have been improved 30 to 40 percent, and refrigeration also increases slightly the cutting efficiency of stock tools which have already received a double tempering operation.

Changes in Micro-Structure

The difficulty in explaining exactly what happens in sub-zero transformation of high-speed steel is that the micro-structure seems to remain constant. However, investigators have decided that the martensitic product of austenitic decomposition, following complete drawing, is in such a finely divided state that the average microscope will not show the change. But the fact that other physical properties do change, indicates a definite step in the same direction as conventional tempering.

Important factors in successful tool treatment are to keep the cooling continuous, whatever the hardening methods, down to at least −110 F. The tool should be allowed to even out, and 2 to 6 hr are required for thorough cooling of average tools.

High-Carbon High-Chrome Steels

Steels, other than high-speed, to which sub-zero treatment is applied are usually those fairly high in alloy. Good examples are high-carbon high-chrome, particularly in the air-hardening variety—both the 12 to 14 percent chrome, $1\frac{1}{2}$ carbon, 1 molybdenum; and the 5 percent chrome, 1 molybdenum, 1 carbon modified high-carbon chrome. Both of these steels tend, on cooling from the hardening heat, to retain austenite. Probably the 5 chrome, 1 carbon, 1 molybdenum is the worst offender. The condition may be the fault of the hardening process used, as well as a characteristic of analysis.

If a part has been pack-hardened and a little carbon has been added, the amount of retained austenite is greater. Then, hardness examination shows the as-quenched structure to be rather low in Rockwell "C" hardness. Such steels have a critical cooling rate that also affects the as-quenched hardness adversely.

Frequently, however, this low hardness cannot be predicted, and it may be determined only by examining the Rockwell hardness after cooling. If, then, the Rockwell hardness is low, a refrigerating cycle can be introduced successfully, even though the steel remains at room temperature for quite a period of time. The same is not true with high-speed, for it must be cooled directly from the hardening temperature to the sub-zero temperature, or maximum transformation will not occur.

However, with high-carbon high-chrome, maximum transformation occurs at about −80 F, and if the tool has been allowed to remain at room temperature for a period of time, hysteresis will probably not have reduced the critical cooling point to much lower than −100 F.

The 5 chrome, 1 carbon, 1 molybdenum steel may come from an air-cooled quench at 58 or 59 Rockwell, after either pack-hardening treatment, atmosphere control, or salt bath, since the time at heat influences the amount of retained austenite. On the $1\frac{1}{2}$ carbon, 1 molybdenum, 12 to 14 chrome steel, a secondary hardness can be reached at about 925 to 950 F. This is an indication of austenite transformation much the same as the reaction to sub-zero temperatures.

However, in tempering at that heat, hardness of the martensite formed on

quenching may be lowered to the point where the new structure, with the austenite that was retained and broken down, will not sufficiently build up the hardness lost in the initial draw. Therefore, it will be beneficial to develop a uniformly transformed structure directly from the quench, if possible.

This is done by refrigerating the tool, if it is low in as-quenched hardness, to a point lower than −90 F. It is kept there about 6 hr, although neither the time the tool is held at the lowest temperature nor the cooling rate is critical. The tool is then allowed to return to room temperature normally. Generally this type of steel will be five to six points harder Rockwell "C" after super-cooling.

A hazard is involved in Rockwell inspection of high-carbon high-chrome steels. Inspection should not be made immediately after the first cycle of refrigeration, since the steel tends to crack through the Rockwell indentation. However, if cooling has been followed by a draw temperature of about 300° to temper sufficiently the martensite formed, little danger will be encountered. In fact, provided that the tool has had a draw of at least 300 to 325°, any type of normal hardness testing can be employed.

Nickel Carburizing Steels

Nickel carburizing steels respond well to sub-zero transformation. In carburizing steels such as SAE 2315, SAE 2512 and any of the other nickel combinations, many engineers find that, whether they quench from the carburizing heat, or drop the heat in the carburizing furnace and then quench, or air-cool and then reheat and quench, the case hardness is much lower than desired. Core hardness will be up, but case hardness is low.

The first step in conventional heat treating is to drop the hardening temperature to the point where the condition of retained austenite does not exist on quenching. At the same time core hardness will be lowered. It is preferable, then, to harden the steel at a temperature that will give the desired core hardness, allowing the case to come as it will.

That is what the sub-zero critical transformation process permits. After the tool has been quenched and tested, the case hardness may turn out to be as low as 58. Some turn out as low as 52 Rockwell "C" scale. That part, if then refrigerated to −120 F, will increase in hardness as much as 12 to 15 points Rockwell "C" in the case, and the core will not be affected. The core is usually low enough in carbon so that there will be little retained austenite.

The high-carbon carburized case, obtained in carburizing, can develop some retained austenite. The hysteresis that is developed on tempering or aging at room temperature is overcome by cooling to approximately −90 to −120 F. If the freezing unit is operating at −60 F, cooling should be continuous, since it is more difficult to break up the austenite at −60 F with this type of steel than it would be at lower temperatures. Lower temperatures are merely a safety factor, because the maximum amount of transformation occurs at about −60 F.

Tungsten Shock Steels

The same procedure holds true with tungsten shock steels as with nickel carburizing steels. Those steels are used today in application where the core requires a good, tough condition, usually around 50 to 55 Rockwell, but higher surface hardnesses are required to resist wear.

The heat-treating procedure includes pack-hardening or carburizing these tungsten shock steels to the point where the case hardness will meet a specification of probably 62 or 62 Rockwell "C." This is, of course, a much greater hardness than originally expected of the steel.

This case hardness can be developed by any of the conventional carburizing media, provided that the quench has been exactly right and retained austenite is not developed. Should the tool quench out in the neighborhood of 58 to 60 Rockwell "C," the next step is to refrigerate, and if this type of steel is taken down to −110 F or lower, the same increase in hardness characteristic is found as in the carburized nickel steels. It is then tempered at 300 F, and the tool is ready for service.

SAE-52100 is a common steel which has

served well in many applications. It can, however, as well as other alloyed steels, develop a condition of retained austenite on quenching.

In one particular case it was used on pump plungers which went into service in varied climates. After about two months of service, the plungers began to stick. Investigation proved that there was evidently a more completely transformed structure after the plunger had been in service. The change in climatic temperature may have caused aging, or this may have resulted from the continuous breakdown into martensite of the austenite that was retained on the quench. Since martensite requires a little more space, the plunger grew. The plungers had been tempered for a long period of time and still there was not complete dissociation of austenite.

A refrigeration cycle was included in the heat treatment of this part, and a thoroughly martensitic structure was developed that did not grow or expand after the plunger had been in service.

In addition, grinding difficulties were far less after the SAE-52100 had been refrigerated. A tempering operation was included after the refrigeration cycle, to temper the martensite formed, since untempered martensite is somewhat brittle. This developed what is ordinarily termed an excellent heat-treated structure.

It has been the standard practice for years for manufacturers to age their gages, so they will not change in size after leaving the factory.

It is common knowledge that, if a tool is not sufficiently drawn, it will develop grinding checks more quickly than one which is thoroughly drawn. Since the sub-zero transformation is really a part of a hardening operation, a more completely drawn structure which tends to grind better is developed.

The same holds true with high-speed steel or the high-carbon chrome steel, and practically any of the carburized nickel steels, since any steel that has retained austenite seems to crack more quickly in grinding.

Sub-zero transformation is rapidly coming to the front. It is quite easy to use, once the equipment is established, and the average user can do a reasonably good job with dry ice.

Dry ice, however, will rarely develop a temperature lower than −70 F. Although the temperature of dry ice is about −110 to −111 F, the temperature is generally around −70° in a container or liquid bath. That is low enough, however, for the carburized nickel steels and the high-carbon high-chrome steels. It will do a pretty good job on tungsten shock steel, but will not be sufficiently low for high-speed treatment.

It seems certain that in the future every hardening room will have some means of refrigeration for the parts being heat-treated, at least those that have found tolerances.

High-Carbon Steels

It does not seem theoretically logical that satisfactory results can be expected from sub-zero treatment of straight high-carbon steels. Nevertheless, one application concerned their use in a cupping punch for drawing steel cartridge cases. The cupping punch is used in the first operation of drawing out a steel cartridge case, and it is a tough one, because at this point the stock is still in its original thickness.

Practically all of the alloyed steels were used in an effort to develop a high compressive strength that would resist cracking in service. Even high-speed steel and high-carbon high-chrome split after a run of around 3,000 cases. Brine-quenched and tempered straight carbon gave similar results.

When straight carbon was considered there did not seem to be sufficient retained austenite in straight carbon steel to cause a weak punch. However, it was treated with a cooling cycle of 24 hr after hardening and tempering, at approximately −70 to −80 F. Production on punches leaped up from 3,000 to more than 30,000 shell cases per punch.

Chilling of Rivets

The riveting of aluminum alloy rivets tends to harden them, which has an adverse effect on their ductility. To offset this, special alloys (No. 17-ST and No

4-ST) were developed, and heat treatment devised to assure the rivets reaching the point of use in a dead soft condition. Present practice calls for the rivets to be reduced in temperature to −40 to −45 F, immediately following the cold quenching operation. Under these low temperature conditions, the No. 17-ST rivet can be held for about 10 days without appreciable age hardening. The No. 24-ST must be conveyed under this low temperature to the point of use and used immediately.

A comparatively recent development is the use of low temperature to secure **expansion fits** in place of shrink fitting. This new technique reverses the operation by chilling the inside part, sliding it into the outside part and allowing it to expand into place on reaching room temperature. The advantage of this procedure over shrink fitting is that it eliminates the hazard of oxidizing and the necessity of final or finishing machine work. Temperatures used in this type of work vary from −50 to −90 F.

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48. PROPERTIES OF METALS AT LOW TEMPERATURES

THE effect of low temperatures on the properties of metals has been given serious consideration only in recent years as the broad application of low temperatures for liquefaction of gases and low temperature processing has been associated with the development of the petroleum industry. Few general deductions can be made except that with decrease in temperature there is an increase in hardness, strength and modulus of elasticity. The effect of low temperatures on ductility and toughness varies considerably among the metals and alloys; the ductility of some metals increasing with decrease in temperature, others show increase in ductility to some limiting low temperature followed by a decrease at lower temperatures, and still others show decrease in toughness and ductility as the temperature is decreased below that normally encountered in the atmosphere.

In **Fig. 1** the relation of tensile strength to temperature is shown for the metals generally selected for structural components. It will be noted that the slope of the curves indicating increase in strength with decrease in temperature, varies among the different metals.

Tensile strength, however, is not a particularly good criterion for determining the suitability of a material for low temperature service as most failures result from embrittlement. Ductility values obtained from the static tensile test may give some clue to the degree of embrittlement, but the notched bar impact test is generally preferred as it is considered to give a better indication of how the material performs under dynamic loading, and the reaction to complex multi-directional stress.

Fig. 2 shows the relation of ductility, as measured by percentage of elongation in

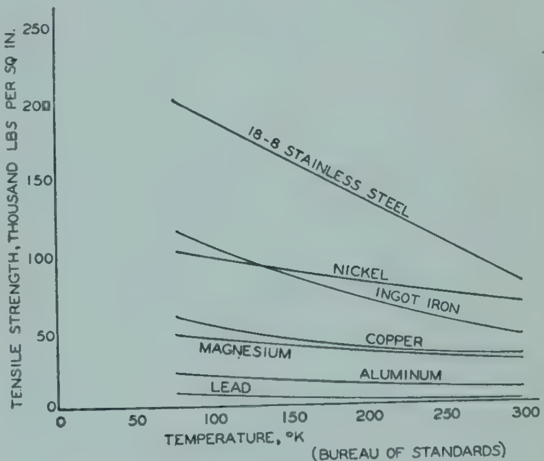


Fig. 1. Relation of Temperature to Tensile Strength of Several Metals.

the tensile test, to temperature for several of the frequently used metals. Of particular note are the curves for copper, nickel, aluminum, and lead which show that ductility of all these metals increase as the temperature is lowered. The three metals iron, zinc, and magnesium show a decided decrease in ductility with decrease in temperature, and at the temperature of liquid air, all of these metals rupture with little plastic deformation, even when tested under static loading.

When these metals are compared on the basis of notched bar impact properties, the same trends may be noted, although the order of magnitude may differ appreciably from that when comparison was made on basis of ductility. For instance, lead has a high order of ductility when determined by the static tensile test, but the resistance to

Thomas N. Armstrong, Author Chapter 48. Born 9/12/04, in Lexington, Kentucky. Educated at the University of Kentucky, BS, 1927. Formerly did open hearth work, Andrews Steel Company, Newport, Ky., 1927–29; Metallurgist, Norfolk Navy Yard, Portsmouth, Va., 1929–35; D & R Division, Intl. Nickel Company, 1935 to date.

Author of some 20 technical papers and articles covering properties, welding and casting of alloy steels.

Member, ASTM; ASM; AFS; AWS; AIME. Awarded the Lincoln Gold Medal by Amer. Welding Society, 1940. During World War II, Research Supervisor for War Metallurgy Committee.

At present, Metallurgist, Development and Research Division, the International Nickel Co., Inc., New York, N. Y.

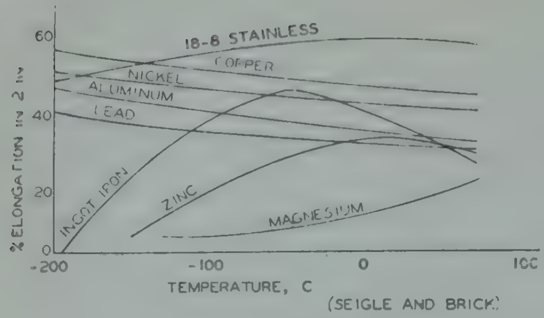


Fig. 2. Relation of Temperature to Elongation of Several Metals.

impact is quite low. Copper and nickel on the other hand have high elongation in the static test and relatively high notched bar impact properties.

The curves in **Fig. 3** show the relation between notched bar impact properties and temperature. The values used for determining the several curves were all not originally reported in the same units so that some allowance must be made for their numerical accuracy although the trends are the same general order, no matter what type of notch is employed.

Except for 18-8 chromium-nickel stainless steel, only the pure metals have been considered up to this point in the discussion, but as alloyed materials are used far more extensively in engineering structures than the pure metals, it is this group of materials that is of greatest interest.

There is very little information on the low temperature properties of zinc alloys. Indications are that zinc die casting alloys respond similar to the pure metal as they suffer a loss in notch toughness with decrease in temperature. Because zinc is not a particularly tough metal by any standard of comparison, neither the pure metal nor its alloys are generally used for members that may be subjected to dynamic or bending stresses of any great magnitude.

The commercial copper-nickel, copper-silicon, copper-tin, and copper-zinc alloys in general are not embrittled by low temperatures.

The commercial high nickel alloys such as nickel-copper, Monel and Inconel are not embrittled at temperatures as low as have been measured.

Lead alloys are seldom given much consideration for low temperature service. Lead-tin solders are as tough at liquid air temperatures as at 70 F, and although the leaded bronzes and brasses usually are not particularly tough at room temperatures, they retain about the same degree of toughness at subzero temperatures as at normal atmospheric temperatures.

Magnesium alloys usually become completely embrittled at temperatures below 0 F.

Aluminum, like copper, nickel and lead, improves in toughness with decrease in temperature, and most of the commercial aluminum alloys respond in the same manner. It should be noted, however, that in general the aluminum alloys which have highest strength properties have considerably lower ductility and resistance to impact than the pure metal.

The low temperature properties of steel have been more thoroughly investigated than those of any other material as steel becomes embrittled at low temperatures, but the embrittling tempertaure is not constant as variations in composition and deoxidation practice have considerable effect.

When steel is in the as rolled condition, or in a mildly heat treated condition such as normalized, annealed or normalized and tempered, carbon influences low temperature embrittlement unfavorably. Rimmed steels are poorer than semi-killed steels and fully killed steels are superior to semi-killed. Use of sufficient quantity of alumi-

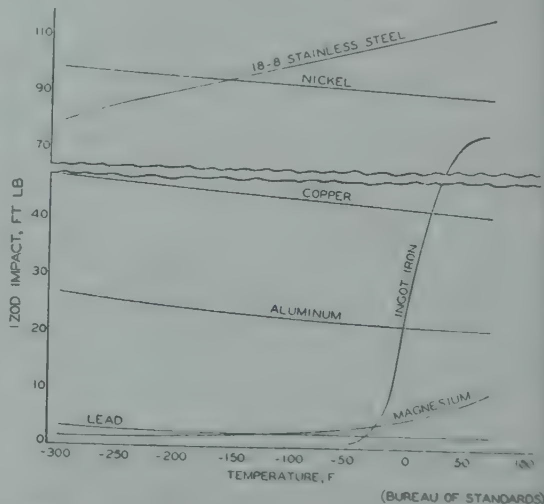


Fig. 3. Effect of Temperature on Izod Impact Properties of Several Metals.

num in deoxidation to insure a few hundredths of a percent of residual aluminum has proven to be of considerable benefit, consequently steels for low temperature service are frequently specified to be made according to fine grain melting practice.

Nickel is recognized as the most effective alloying element for increasing resistance of steel to low temperature embrittlement. The temperature at which embrittlement occurs decreases with increase in nickel content up to about 15 percent nickel. With higher percentages of nickel, the impact properties of low carbon steels become practically non-variant at temperatures below atmospheric as shown in **Fig. 4.** Other alloys may exert a mild influence in improving the resistance of steel to low temperature embrittlement, but their effect is generally an indirect one of modifying the form and distribution of the carbides rather than a direct alloying effect on iron as occurs with nickel.

Condition of heat treatment has a marked effect. In the fully annealed condition, steels are in the poorest condition for resisting embrittlement, and although considerable improvement usually results from normalizing and further benefits are secured by a tempering or stress relieving treatment, best properties are obtained when the steel has been fully hardened, followed by tempering to moderate hardness levels. Even carbon steel, when fully

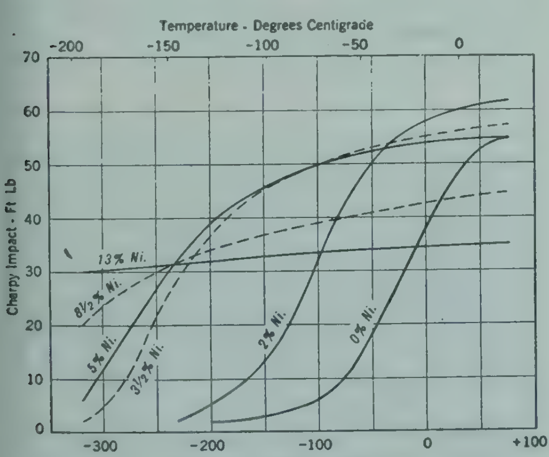


Fig. 4. Effect of Nickel Content on the Resistance to Low Temperature Embrittlement of Normalized Low Carbon Steels. (Keyhold notch.) All steels contain 0.01% carbon except No. 1020 (0.20%) and 2% nickel steel (0.15%).

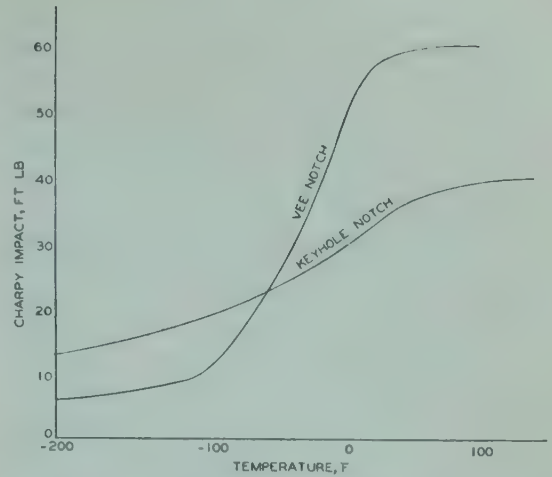


Fig. 5. Effect of Different Types of Notches on Impact Properties of a Normalized and Tempered Cast Nickel Steel.

hardened and tempered, possesses a considerable degree of toughness at liquid air temperatures despite the fact that the same steel may break brittle at temperatures above 0 F when tested in the as rolled or in the normalized condition. It should be recognized, however, that with commercial quenching practices, carbon steels will not completely harden through in thicknesses greater than a few tenths of an inch, and the most frequently used alloy steels of the SAE or AISI types will not harden completely on quenching in oil if the section is greater than about one inch in diameter.

Even though the notched bar impact test has been the most widely used test for determining the suitability of metallic materials for low temperature service, the test has not received universal approval as the values are reported in energy units absorbed in breaking the specimen and cannot be applied quantitatively in design. Some question has been raised as to whether values obtained on notched specimens approximately 0.4 inches square reflect behavior of full size sections used in engineering structures. Also, considerable support has been given to the concept that the mode of propagation of fracture, i.e. shear or cleavage, is of greater importance than total energy to rupture. Still another group advocates that the amount of plastic deformation be used as the criterion.

Most commercial specifications for ma-

terial for low temperature service specify Charpy specimens with keyhole notch. This type of specimen is not quite as sensitive to small differences in properties as the Charpy bar with vee notch. Characteristic curves for the two types of notches are shown in **Fig. 5.**

There are a number of other types of notch tests that have been proposed for replacing the Charpy test such as the Kahn tear test, the Penn State slow notch bend test, the Lehigh slow notched bend test and a modified form of a ballistic test.

Any of these tests can be used for determining the transition temperature of steels (the temperature distinguishing between ductile and brittle behavior), but the transition temperature determined by any one test is not necessarily the same as that determined by another test method. In fact, the type of transition curve, **Fig. 6,** may change with the test method, and if the criterion is based on a condition of fracture common to all tests, such as 50 percent cleavage and 50 percent shear, transition temperature may vary as much as 50 F or more in the same steel when tested by different methods. It must be recognized that the temperature, the speed of load application and the degree of restraint all affect the temperature of change from ductile to brittle behavior in any particular steel, and as these variables change with methods of test, it is not surprising that these differences in transition temperature are observed. Until a universally accepted test method is developed, the engineer can do little better than accept arbitrarily established limits that qualitatively indicate a level of toughness sufficient to meet service requirements. The ASME Boiler Construction Code for Unfired Pressure Vessels and the ASTM Specifications require that the steel must meet a minimum of 15 ft lb Charpy, keyhole notch, at the minimum service temperature.

There are problems connected with selection of material for low temperature service other than the low temperature behavior of the material under a controlled set of conditions. The matter of cost is a paramount one and involves not only the unit price of the material, but the cost of fabrication. The type of fabrication re-

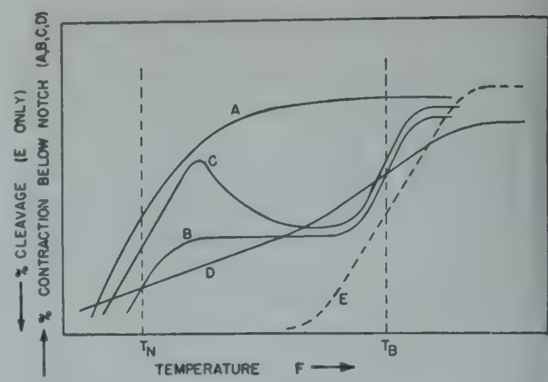


Fig. 6. Diagram Showing Types of Transition Curves Obtained on Notched Specimens. Using percent contraction below the notch in A, B, C, and D; percent cleavage in E.

quired may be a controlling factor, and of equal importance may be availability of the material in the sizes and forms required. If special skills are required for fabrication, facilities may not be readily available. Each of these factors should be weighed before making the final selection.

Quenched and tempered low alloy steels of the AISI or SAE types frequently are used in light and moderate sections of machinery parts that are to operate at temperatures down to −150 F. A type of steel should be selected that will fully harden on quenching, and if any welding is performed, it should be done prior to the quenching treatment.

For structural components, aluminum treated low carbon steel frequently is used in light sections for temperatures down to −50 F; low carbon nickel steels containing

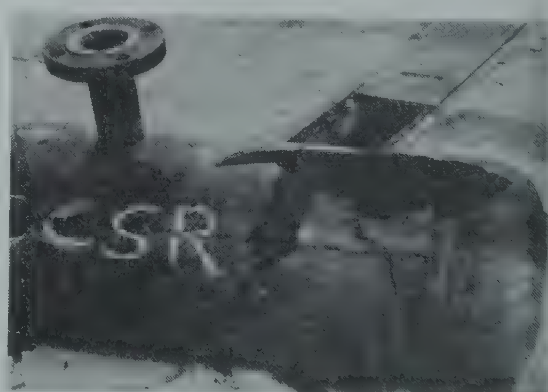


Fig. 7. Vessel of Carbon Steel, A201, Welded with Carbon Steel Electrodes, Stress Relieved 1200 F, Tested at −320 F, 1000 Ft Lb.

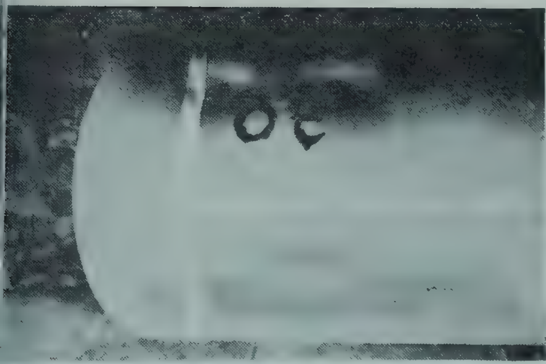


Fig. 8. Vessel of $8\frac{1}{2}$% Nickel Steel, Welded with 25-20 Stainless Electrodes Reheated to 1050 F, Tested at −320 F, 3000 Ft Lb.

up to about $3\frac{1}{2}$ percent nickel are generally selected for temperatures down to −150 F, and copper and copper alloys, nickel and Monel, chromium-nickel stainless steels, aluminum alloys and low carbon high nickel steels all have been used for temperatures below −150 F.

The choice of materials for large pressure vessels and towers has probably received more attention than any other phase of the low temperature problem. Because of almost universal use of welded construction for these parts, it is essential that a material be used that can be welded by an accepted commercial process, and that welds have resistance to low temperature embrittlement approaching that of the base material. In addition, the properties of the base material must not suffer deterioration from the heat of welding, or at least to a degree that cannot be corrected by a simple form of heat treatment such as

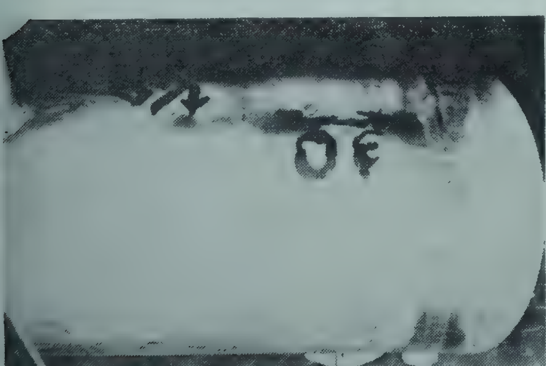


Fig. 9. Vessel of Type 304 Stainless Steel, Welded with Type 304 Electrodes Tested as Welded, −320 F, 3000 Ft Lb.

a stress relief anneal. This immediately eliminates steels that derive their resistance to low temperature embrittlement from full heat treatment. As rolled or normalized, aluminum treated low carbon steel, welded with AWS 6015 electrodes, is used for comparatively thin wall vessels for temperatures down to −50 F. Low carbon, $2\frac{1}{4}$ percent nickel steel welded with AWS 8015 nickel steel electrode generally is used for temperatures down to −75 F or slightly lower, and low carbon, $3\frac{1}{2}$ percent nickel steel, welded with AWS 8015 nickel steel electrodes, has been employed for temperatures down to −150 F.

For temperatures below −150 F the engineer has a choice of a number of materials. Copper and copper-base alloys meet the low temperature requirements, but special skill is required for making welds in heavy plate. Nickel and Monel are satisfactory from almost every consideration except cost. Chromium-nickel stainless steel has probably been used more extensively than any other material, but here again, cost is an objectionable feature. The principal problem associated with its use is selection of electrodes that will develop suitable low temperature properties in the weld, and at this time types 304 and 310 electrodes appear to best meet the requirements.

Aluminum alloys have been receiving increasing attention and offer certain advantages, among which is their moderate cost. The aluminum alloys that have best welding qualities are limited to those of tensile strength of less than 20,000 psi. There are also certain problems associated with the welding of thick sections of aluminum alloys that have not been completely solved as yet. It should be recognized that while most of the aluminum alloys are not embrittled by low temperatures, their notched bar impact properties generally are considerably lower than the minimum required in steel.

The recently developed low carbon high nickel steels offer considerable promise for use at temperatures below −150 F. They retain a considerable degree of toughness at temperatures down below that of liquid nitrogen, they possess high strength and ductility and may be welded satisfactorily

by any of the commercial welding processes. Electrodes for arc welding have been limited to type 310 stainless and 80 percent nickel-chromium alloy, as welds made with ferritic steel electrodes have not had the required impact properties at very low temperatures. The unit cost of this material is somewhat lower than the cost of any of the non-ferrous metals and fabricating costs compare favorably with those for low carbon steels. **Figs. 7, 8,** and **9** show results obtained with vessels constructed of carbon steel, low carbon 8½ percent nickel steel and chromium-nickel stainless steel when filled with liquid nitrogen and subjected to the blow of a freely falling weight.

Cast iron is usually considered a brittle material at normal atmospheric temperatures, but there are many applications where it is used successfully, even when some degree of shock resistance is required. Impact measurements on cast iron usually are made on unnotched arbitration test bars 1.2 inches in diameter, and although the resistance to impact decreases as the temperature is lowered, a sharp transition temperature has not been observed. The plain cast irons have very low resistance to impact, both at room and low temperatures, but some of the alloyed cast irons possess a moderate degree of toughness. The high alloy irons of the Ni-Resist type have appreciably higher toughness, but both the low alloyed and Ni-Resist types show a drop of 25 to 30 percent in impact values from room temperature down to −300 F. Since the impact resistance of low alloyed high strength cast irons is of the order of 25 to 30 ft lb at room temperature, and that of Ni-Resist 80 or more ft lb, the impact values at −300 F are about 20 ft lb for grey iron and 50 to 90 ft lb for Ni-Resist. These values cannot be compared with impact properties of steels and metals that are measured with notched specimens about 0.4 inches square, as such specimens are unsuitable for measuring differences in metals that are inherently brittle.

If you searched this chapter for something which was not found in it, please let the editors know.

49. LOW TEMPERATURE TEST EQUIPMENT

THE diverse needs of the armed forces in waging total war on several fronts have brought about the necessity for a great deal of low temperature testing, a subject given little or no consideration prior to the war. The principal need for testing at extremely low temperature has been brought about by campaigns planned for arctic climates such as Alaska and Russia, with the greatly expanded use of the airplane in substratosphere and stratosphere flying. Aircraft first attempting to penetrate these high levels experienced serious difficulty with the failure of instruments, control apparatus and plane equipment, due to unequal expansion and contraction, hardening of lubricants, solidification of plastic and flexible material and even to changes in the molecular structure of metals and other materials. The same effects were encountered with ground equipment in arctic climates.

Typical examples of items which are currently subjected to cold tests are altimeters, tachometers, automatic pilots, bomb sights, clocks, radio sets, oil pumps, auxiliary engines, electric meters, oxygen regulators, synthetic materials, hydraulic hose line, cameras, landing gear elements, etc. Much of this equipment is tested at the end of the production line to determine that each individual instrument or device will function effectively when subjected to low temperatures or to extreme changes in temperature, while development tests are common on behavior of welded and riveted structures, aircraft parts, tank armor, land mines, etc.

WILLIAM J. AULSEBROOK, Author Chapter 49. Born 8/7/96, in Douglas County, Colorado. Educated at the University of Colorado, BS, 1918. Formerly Radio Instructor, Vocational Army School, Colorado University, 1918–19; Mill Student, Great Western Sugar Co., Ft. Collins, Colo., 1919; Farm Light Sales, Western Electric Co., 1920–21; Grainfield (Kansas) High School Principal, 1921–24; Radio and Refrigeration Field Engineer, Globe Electric Co., 1924–26; Commercial Engineer, Mountain Div., Servel, Inc., Denver, Colo., 1926–28; Applications Engineer, Servel, Inc., Evansville, Ind., 1928–32; Applications Mgr., Servel, Inc., 1932–35; Asst. Sales Mgr., Servel, Inc., 1935–45; Sales Mgr., Elec. Refrign. Div., Servel, Inc., 1945–49; Assistant to the General Manager, Elec. Refrign. Div., Servel, Inc., 1949 to date.

Author of numerous articles in ACRN, Meat Merchandising, *Refrigerating Engineering;* Chapter 44, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engrs.; Program Committee 1948–49; Refrign. Service Engrs. Society; Advisory Committee, Quartermaster Corps, US Army.

At present, Asst. to the General Manager, Elec. Refrign. Div., Servel, Inc., Evansville, Ind.

Temperature and Load Calculations

Data collected over a long period of time by the weather bureau indicate a median temperature of −50 to −60 F at altitudes above 30,000 ft and scattered observations have revealed areas of even lower temperatures. As a result of these findings the tendency has been to standardize on production tests at −58 F and to "spot check" a percentage of critical items at temperatures as low as −100 F.

In addition to the low temperature tests, it is not uncommon to find it necessary to test the same apparatus at relatively high temperatures, since aircraft or other mobile equipment may be subjected to sun exposure in hot climates, temperatures running up to 160 F. Test chambers have been built in which it is possible to heat to 160 F or higher, chill to −60 F or lower, and at the same time maintain atmospheric pressures anywhere from normal sea level conditions to 50,000 ft. Specific humidity conditions are also controlled.

Load determination is of extreme importance in this work, and approximate methods must be discarded. The load sources commonly encountered in low-temperature test work may be summarized as follows:

Leakage. The heat entering the cabinets by virtue of transfer through the wall structure is subject to calculation by conventional methods, provided the *K*-factors for all insulating materials are accurately known. Special care should be taken to allow for transfer through framing elements, breaker strips and conductive parts projecting through insulation. The conductivity should be based on experimental data at the approximate temperature level to be attained. Increases of as much as 100 percent have been observed at extreme temperatures.

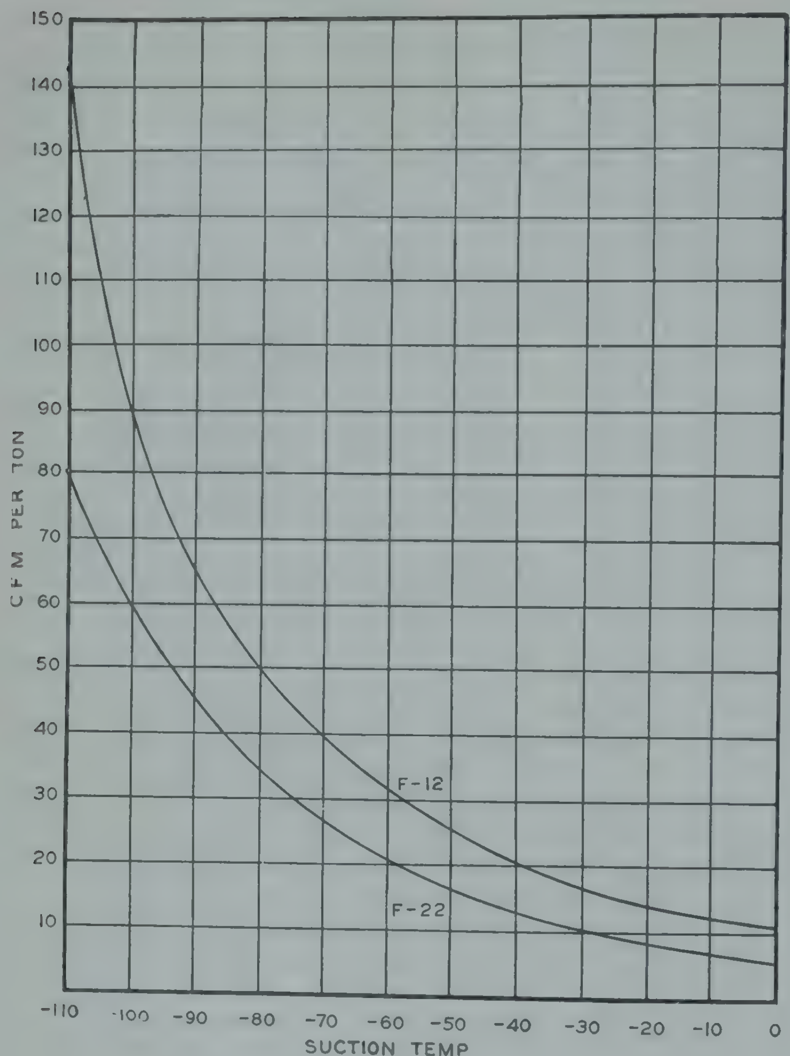


Fig. 1. Refrigerant Displacement per Ton at Low Temperatures. Approximate Net Displacement in cfm per Ton for Sub-Zero (1st Stage of Multiple-Stage Units).

Air change. If the method of operation requires frequent opening of the cabinet when at low temperatures, a careful determination of the sensible and latent heat load caused by air change should be made.

Product load. The weight and specific heat of each load must be carefully determined. Many devices to be tested in subzero spaces are operated by electricity or other means, and the heat thus introduced must be accounted for at 3415 Btu per kw hr. This includes the input to fan motors in case forced convection evaporators are used. If motors are mounted outside, with the drive through shafts, the net losses in heat radiated to the room may be eliminated, leaving only the heat equivalent of the useful work done as an addition to the refrigeration load. (For small motors the saving will amount to 25 to 40 percent of the total motor input.)

Many tests are designed to start with the cabinet and apparatus at room temperature or above, in which case the greatest single source of load may be the sensible heat from cabinet walls, insulation, evaporator and product. For practical purposes it is safe to assume that the liner, evaporator and approximately one-half of the total insulation weight must be cooled through the entire range.

Choice of Systems and Containers

It is theoretically possible to use almost any refrigerant for low-temperature work, but, practically, the field narrows down to Freon-12, Freon-22 and methyl chloride. The last-named, being to some extent flammable and under certain circumstances toxic, has found little acceptance. Freon-12 has been used most widely for temperatures down to −75 F in properly designed

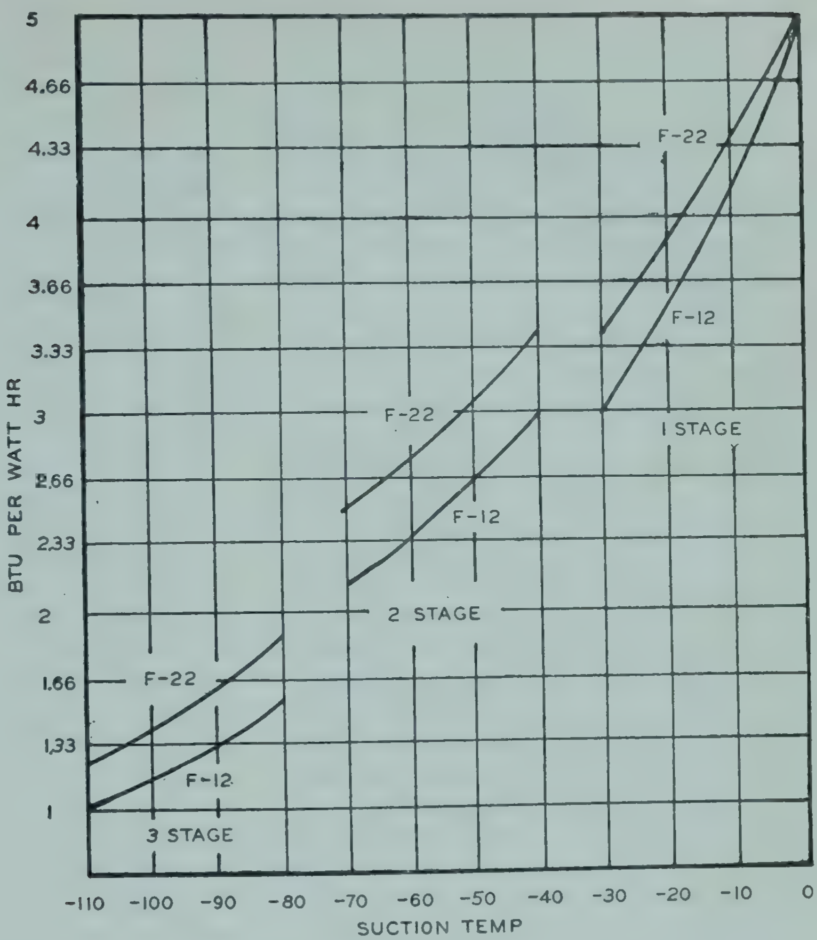


Fig. 2. Performance of Condensing Units in Sub-Zero Conditions. Approximate Performance of Production Condensing Units in Sub-Zero Work.

two-stage systems, and, with three-stage operation, it has been possible to reach −90 F. At lower temperatures, the evaporator pressure becomes so low that the efficiency is impaired by incomplete filling of the cylinders. Freon-22 has made it possible to obtain, with both two-stage and three-stage systems, temperatures approximately 10 to 15° lower than with Freon-12. **Figs.** 1 and 2 provide refrigerant data for the low-temperature range.

Designing cabinets or rooms for extremely low temperatures involves an extension of known practice; insulants having low *K*-factors, resistance to moisture and low specific heat are preferred; framing with metal, wood, or other materials having a high conductivity should be kept to a minimum; and breaker strips which serve to seal the wall structure between the inner and outer liner at door openings should be given special consideration. Care should be exercised to select light material for liners. Cabinet manufacturers have used a multiplicity of thin steel sheets having a surface resistant to radiant heat (Ferro-therm), and silica gel (Santocel), where the load in rapidly changing temperature is heavy.

Evaporators are of the forced convection and plate types. In applications in which frequent heating and cooling are involved, the forced convection evaporator has a distinct advantage. The plate type coil has found more general acceptance in those applications in which the cabinet is to be chilled to a predetermined low temperature and held there for long periods. It is easily defrosted while cold, maintains a uniform temperature on relatively long cycles and, when used as a part of the cabinet wall, occupies a minimum of space. The heat absorption per degree temperature difference on either of these two types of evaporator remains substantially the same as has been obtained on similar evaporators in the higher temperature brackets, but, because of the rapid increase in size and cost of condensing units as evaporator temperatures go down, every effort should be made to improve the evaporator performance in

order to reduce to the lowest practical level the temperature difference between refrigerant and space. That is, one must incorporate the largest amount of surface consistent with available space, and design the refrigerant passages, air flow, etc., to utilize this material at its highest efficiency. The pressure drop must be held to a minimum because it handicaps the performance of the condensing unit, yet reasonable velocities are necessary to obtain efficient transfer. Because of these divergent factors, a "tailor-made" evaporator based on considerable trial-and-error experimenting is usually necessary to obtain the best results.

A word of caution may be in order in connection with variable **atmospheric pressures.** In those cases in which altitude conditions are simulated by simultaneous reduction of pressure and temperature, it will be found that the heat transfer on the evaporator drops very rapidly as the atmospheric pressure is reduced. This occurs because of the reduction in weight of the circulating air and apparent drop in basic transfer factors. For the same reason, the rate at which heat is removed from apparatus under test is likewise reduced. Conditions may exist in which a warm object will remain for hours in a cold chamber with no appreciable lowering of temperature. It is therefore advisable, when possible, to reduce temperature under full atmospheric pressure, and then start the vacuum pumps to simulate "climb."

Condensing Units

A comparatively poor compressor will behave satisfactorily when applied to air conditioning, with a compression ratio of about 3 to 1, with a volumetric efficiency of, say, 75 percent. The efficiency of this compressor may, however, drop as low as 20 percent at −30 F, where the compression ratio is roughly 15 to 1. Re-expansion of the gas in the clearance space, leakage past pistons and valves, pressure drop through imperfectly designed suction passages, and stiff suction and discharge valves cause this effect. By scrupulous refinement of details, a single-stage compressor can be designed which will develo some appreciable output at evaporatc temperatures as low as −50 or −60 and some mine-run compressors will be have fairly well at these temperatures. Bu high efficiency is impermanent—a littl bearing wear will increase clearance vol ume, continued operation impair the be havior of valves. The practical problem i to hold the compression ratio down t those levels at which normal compressor show good efficiencies, by means of multi ple-stage operation.

Physically, there are two methods o carrying out this operation in common use the cascade and multiple-compression sys tems. In a **cascade system**, the first or low pressure compressor discharges into a hea exchanger from which the second compres sor takes its refrigerant to be compressed into another heat exchanger, which in turn may be taken up by a third compressor. This system offers the advantage that re frigerant circuits are comparatively simple each assembly having its own refrigerant valves, and control. When desirable, two or perhaps three different refrigerants may be used. The disadvantages lie in the fac that there must be a definite temperature difference in each heat exchanger to trans fer the heat from one stage to the next. The second disadvantage is in the fact that, in the lowest stage especially, the total pres sure available from the condenser may be so low as to make it difficult to control expansion valves or other pressure-restrict ing devices with any degree of accuracy. For example, in a three-stage system there might be the circumstance of a suction pressure of, say, 28 in. vacuum and a head pressure of 6 in. vacuum; the total differen tial available will not give satisfactory refrigerant flow through standard expan sion valves.

By the **multiple-compression** method the first compressor discharges into the second and the second into the third, thus maintaining the lowest possible compression ratio per stage. Here the condensing pressure is high enough to actuate ordinary expansion valves. The chief disadvantage is that the refrigerant fed to the seco and successive stages is highly supe

heated, causing compressor overheating. Moreover, the refrigerant fed to the low temperature evaporator comes from a comparatively warm condenser, and thus generates a very high percentage of "flash gas" at the valve. As a means of overcoming both of these disadvantages, the liquid subcooler illustrated in the system shown in **Fig. 3** is a necessary part of all multiple-compression systems. In this device the high-pressure liquid from the condenser is split after leaving the condenser, one portion passing through a tube or tubes in a heat exchanger, a smaller one being fed through an expansion valve surrounding these liquid-carrying tubes of the heat exchanger. It will be observed that 100 F refrigerant from the liquid receiver can be reduced below 0 F before being fed through the main expansion valve, and the flash gas which would otherwise have been generated is bypassed around the first stage and fed into the second stage. In practice the use of this device saves approximately one-third of the displacement in the first stage.

By proper adjustment, a saturated refrigerant may be fed back into the second stage to mix with the highly superheated discharge gas from the first stage. This materially reduces the heating of the second-stage compressor and improves its over-all efficiency.

Using Freon-12, it is possible to attain fairly satisfactory **efficiencies** on two-stage units at evaporator temperatures as low as -75 F, at which point the compression ratio per stage is approximately 8 to 1. It is advisable to resort to the third stage if the temperatures must be carried lower. By substituting Freon-22, the absolute pressure in the evaporator will be increased by about 2 lb per sq in. Evaporator temperatures can be dropped to -110 F with Freon-12, or -120 with Freon-22, while maintaining acceptable over-all efficiency. Using extra light suction valves with little or no spring tension will allow the cylinder to fill reasonably well at 0.75 .0 lb absolute as a minimum.

The simplest and most obvious procedure in setting up a multiple-compressor system would be to use two or three conventional compressors driven by separate motors, and inter-connected so that the compressed gas progresses from the discharge of the first compressor to the suction of the second and the discharge of the second to the suction of the third, finally passing into a conventional condenser-receiver assembly.

A modification making for compactness involves the mounting of two compressors on opposite ends of a common base having one driving motor between. Further simplification can be achieved by arranging the interior passages and valves of a single compressor so as to include two or even three stages of compression in a single compressor body. This latter practice has been common in air compression for many years. With modifications to accomplish proper oil return it has been found satisfactory for refrigeration, as in **Fig. 4**.

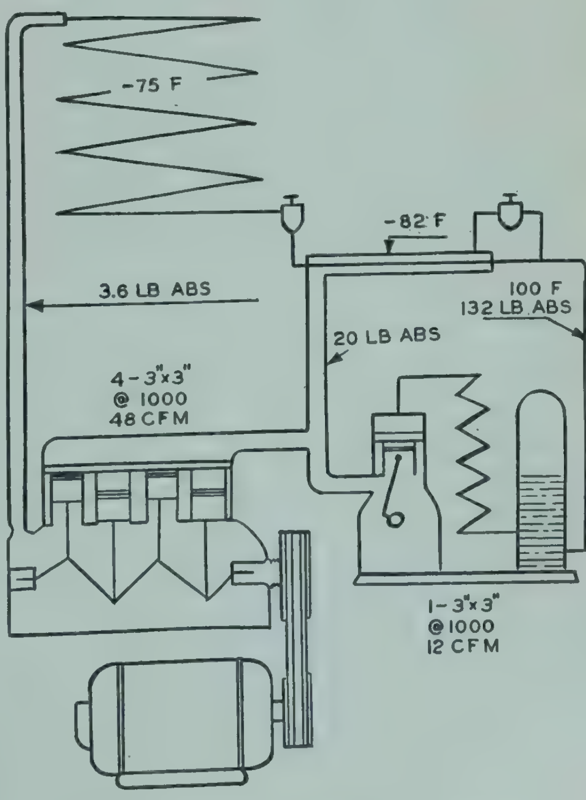


Fig. 3. Diagram of Two-Stage F-12 System.

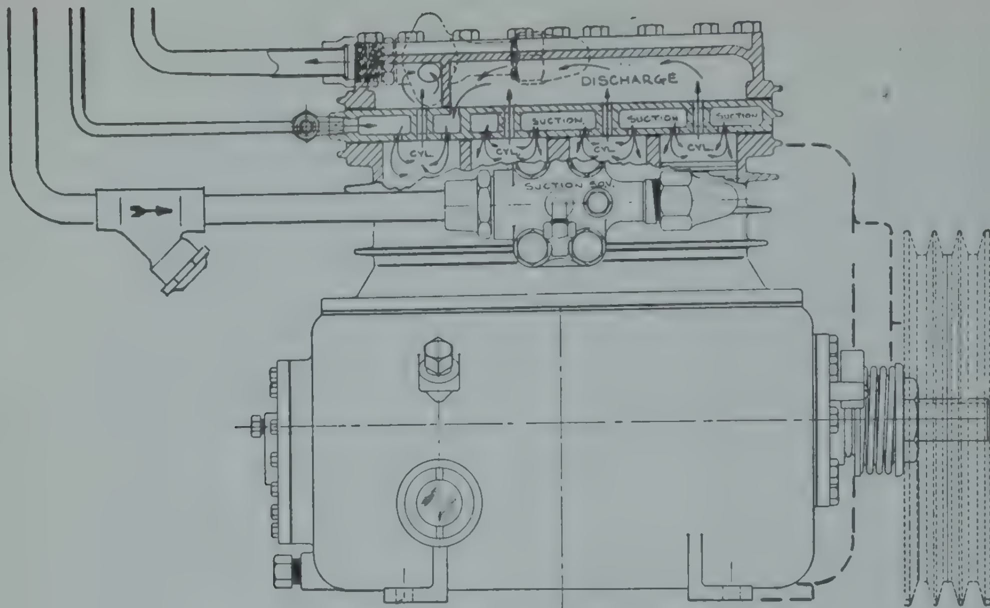


Fig. 4. Section of Two-Stage Compressor.

Lubrication

There are no commercially available lubricants which have satisfactory viscosities at normal temperatures, in which the pour and dewaxing points are lower than −20 or −30 F. It has been found that there are several high-grade lubricants having satisfactory characteristics which do not congeal or dewax to any appreciable extent, provided that they carry in solution a reasonable proportion of liquid refrigerant. This means that a high-side oil separator is not essential to the successful performance of these low-temperature units, provided the evaporators are designed with consideration for maintaining reasonable velocities so that they do not trap oil, and provided the refrigeration feed devices are so adjusted as to carry a reasonable saturation of liquid refrigerant.

Within the compressor, however, it has been found that special precautions are necessary to prevent overheating of the lubricant, which is not experienced to the same degree in conventional commercial applications. Since these multi-stage compressors have a tendency to overheat it is necessary that most of the heat of compression be radiated to the atmosphere or water jacket. Auxiliary oil coolers can be applied to compressors having forced lubricating systems. Experience indicates that such oil coolers should be designed to hold lubricant temperatures below 140 F, if possible.

Controls

Float or **expansion valves** may be used in this field. One of the valve manufacturers has announced a differential temperature valve which would appear to offer advantages. It is actuated by two bulbs, which permit charging the actuating elements with a gas of relatively high vapor pressures to insure adequate motive power even at extremely low temperatures.

It has usually been found necessary to incorporate means for cutting off the refrigerant flow in the liquid line when the refrigeration system is shut down or when it cycles to maintain specific temperatures. If the liquid line is not closed off and the evaporator pumped down when there is a shutdown, the pressures existing in the evaporator at the beginning of the next running cycle are likely to be so high as to prevent the restarting of the system without severe overload of motor, condenser, or even compressor elements.

It has become good practice, therefore, to install a dependable **solenoid valve** in the main liquid line or in the branch liquid lines ahead of each expansion valve, with a special thermostat to break the current

and close the solenoids when correct temperatures have been attained. A switch permits manual shutdown on the same basis.

The conventional commercial **pressure control** is not generally adjustable to the low vacuum points encountered in sub-zero work, as most of them have a bottom cut-off around 20 in. vacuum. It is necessary, therefore, to use a special low-pressure control or connect the pressure control in the second stage where the pressure will substantially parallel the first stage suction pressure, but will not drop to the extreme low points which are outside the range of conventional controls.

It is advisable also to connect a second low-pressure control in the second stage as a precaution against overloading motors during the pulldown cycle. It is customary to load the motors for this type of equipment so that they carry the maximum at a main evaporator temperature ranging from −40 to −70 F. The motor loads may run 100 to 200 percent above the design figure, if a free and unrestricted flow of refrigerant into a warm evaporator is permitted.

Most **thermostats** are of the pilot type, operating on low voltage or at least carrying only relatively light currents. Relays are, therefore, usually necessary in the main circuits operating motors and solenoid valves.

Installation

Mechanics handling this type of work must have a full understanding of the problems imposed by sub-zero operation. Suction and liquid lines should be of copper, because this material can be more easily soldered, is cleaner, and is less susceptible to oxidation than steel or other materials. Where joints are necessary, they should be hard-soldered or brazed, except on the smaller sizes in which a carefully made SAE flare fitting is acceptable, if the joint is not subjected to strains of vibration. Flexible vibration absorbers should be used.

Liquid sub-coolers, heat exchangers, and even the suction lines adjacent to the cabinets should be carefully **insulated** with moisture-resistant insulation. Methods which have proved satisfactory for higher temperatures must be refined and extended to assure permanence at low temperatures.

All **electrical lines** should be installed in metal conduit, joints carefully soldered and protected with rubber and water-proof taping. The extension of electrical wiring into the refrigerated space should be minimized. Ordinary lubricating oil in bearings will cause motors to stick. Glycerine and Prestone have proved to be satisfactory lubricants. Alcohol or volatile petroleum products should not be used to thin the oil in cabinets subjected to a heating cycle, due to the hazard of fire and explosion.

Multiple-stage compression equipment is potentially dangerous. If a three-stage system develops a leak in the low side of the first stage, permitting air to enter the system under a deep vacuum, the successive stages of compression might easily build up pressures of more than 1000 lb per sq in. in the condenser of the final stage. Such systems should have not only the usual high-pressure cut-out, but **safety relief valves** on the final stages. High pressure electrical cut-outs should preferably be of the manual reset type with auxiliary alarm connections. Receiver-condenser assemblies should be capable of holding the entire refrigerant charge. A high-pressure cut-out will not adequately protect against rupture due to hydraulic action, since the pressure sometimes builds up so rapidly that the control does not have time to act.

A sub-zero system should be under the supervision of a skilled engineer for a period. Expansion valves, thermostats, pressure controls and safety devices should be subjected to repeated checks. Recording instruments should be installed to permit a study of all parts under operating conditions. Compressors, oil levels, lubricant pumps and oil coolers should be checked at frequent intervals; refrigerant flow, oil return and general operating characteristics should be studied.

If you searched this chapter for something which was not found in it, please let the editors know.

50. STRATOCHAMBERS

STRATOCHAMBERS have a very wide application, especially when used for equipment tests. To present design details, it is necessary to narrow the scope of this section to one of the most common applications, physiological tests. The following specifications and calculations are typical, and have many points in common with chambers used for other purposes.

Specifications

Pressure. Vacuum equipment should be of sufficient capacity to reduce the pressure inside the chamber from that at sea level to the low pressure existing at 45,000 ft altitude in 4 or 5 min. It should maintain pressure equivalent to that at 45,000 ft altitude with a fresh air "bleed" into the chamber of approximately 10 cu ft per min. This 10 cfm of fresh air is necessary for ventilation, since oxygen masks are in continuous use inside the chamber and the oxygen concentration there is high. The vacuum pump equipment should be lubricated and sealed to handle air of high oxygen concentration without any danger of explosions.

Temperature. Refrigeration equipment should be designed to reduce the temperature within the chamber from normal atmospheric conditions (+70 F) to −70 F in not more than 12 min, paralleling the reduction of pressure from sea level to that of 45,000 ft altitude. It should also be of sufficient capacity to hold the −70 F temperature after the 45,000 ft altitude condition has been reached.

Size. The chamber should be large enough to accommodate six men in flying clothes.

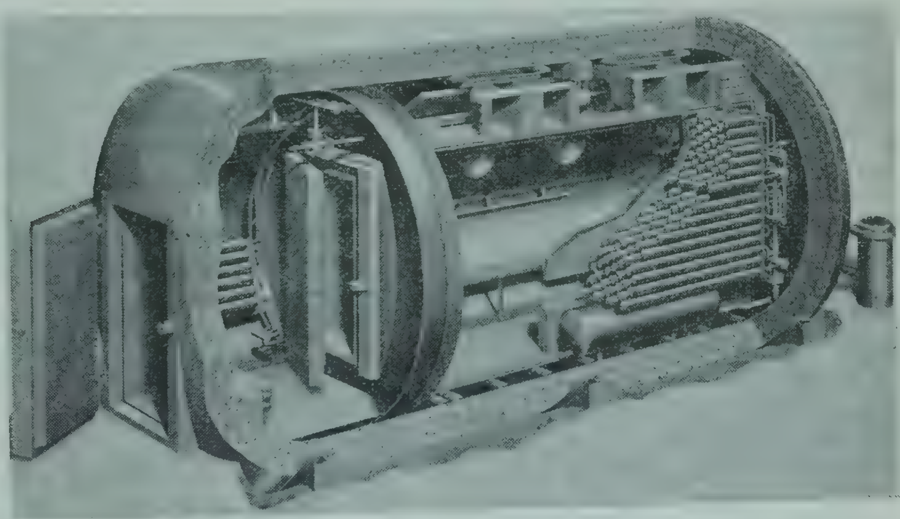


Fig. 1. Perspective of Stratochamber for Physiological Research.

Refrigerating capacity. The refrigerating capacity should be sufficient to obtain the rapid temperature reduction mentioned above and maintain −70 F inside the chamber, with the following internal heat load:

a. Six men in electrically heated suits.
b. 500 watts of light.
c. 10 cfm of ventilation air.
d. Approximately 1 kw of motor load.

Fig. 1 shows a cutaway picture of a typical stratochamber for physiological research. The chamber is divided into a lock approximately 4 ft long and a main chamber approximately 18 ft long. Inside the

JOHN G. BERGDOLL, JR., Associate Editor Section VI and Author Chapter 50.

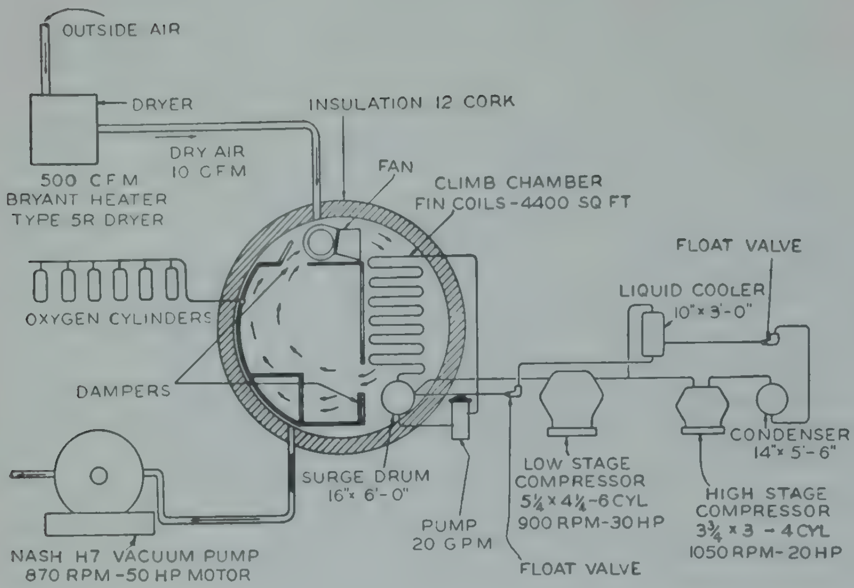


Fig. 2. Stratochamber Parts and Connections.

main chamber an insulated "climb" chamber is constructed with space on one side for the refrigerant coils, and a plenum space between the "climb" chamber and main chamber for circulation of air. By means of dampers, the climb chamber can be completely isolated from flow of air from the refrigerated space.

Refrigeration is supplied by a two-stage Freon-12 system operating normally at −85 F suction temperature; evaporator coils are fed from a Freon-12 liquid circulating pump, which insures continually efficient coil operation without danger of liquid "slugs" to compressor.

Fig. 2 shows diagrammatically the stratochamber with major accessories. These consist of the fresh air drying unit, oxygen cylinders for supplying oxygen to masks, vacuum pump for evacuating chamber and the refrigerating machinery.

The following tabulation of **lines and connections** into the chamber gives some idea of the multiplicity of passages through the walls.

	In climb chamber	*In lock*
Vacuum pump suctions	2	1
Air inlet	1	1
Drain	1	1
Barograph	1	1
Altimeter	1	1
Thermometer	4	2
24-ga telephone pairs	1	1
12-ga telephone pairs	1	1
Oxygen lines	2	1
40-volt conduits	2	1
110-volt conduits	2	1
220-volt conduits	1	1
Teletalk & push button	1	1
Observation ports	3	1
Instrument lock	1	–
Emergency air	2	1
Extra connections	36	14
Approximate Total	62	30

Operating Cycle

The cycle of operation is as follows: The climb chamber is opened to the refrigerated space with fans in operation and the refrigerating equipment operated for a sufficient length of time to pull all the heat out of the coils, shell, and insulation. This takes from 15 to 20 hr. During the last several hours fans are not operated and air flows by gravity down through the coils and up through the climb chamber, back to the coils. The coils and shell are sub-cooled to a temperature of −90 to −100 F, considerably below the final temperature to be produced in the climb chamber.

At the end of this preliminary cooling period, the climb chamber is isolated from the cooling circuit and heated up to normal atmospheric conditions by means of electric heaters. The chamber is then ready for the test period.

After the test subjects have been put into the climb chamber, the vacuum pumps and fans are started and the dampers admitting cold air to the climb chamber are opened. A sufficient reservoir of refrigeration has been built up to reduce the temperature within the climb chamber to −70 F in 12 min or less.

Typical **design calculations** appear in **Table 1.**

Table 1. Summary of Loads at −70 F Btu/hr

a. Heat leakage through insulation connections, plus heat flow out of insulation after 20 hr operation.	
(1) Chamber 630 sq ft×.1 [90−(−70)]	**=10,080**
(2) Lock 260 sq ft×.1 [90−(−70)]	**= 4,160**
b. Light, 500 watts, 500×3.415	**= 1,708**
c. Fan motor at 40,000 ft elevation, .8 kw ×3415	**= 2,730**
d. Six men in heated suits, 6×1,380	**= 8,280**
e. 10 cfm of dry air (90 F to −70 F)	**= 1,800**
f. Refrigerant pump, .373 kw×3,415	**= 1,272**
Total for Climb Chamber and Lock	**=30,030**

Under (a) above it is to be noted that a heat leakage factor of 0.1 Btu per hr per °F is used instead of the normal factor of .025 Btu per hr per °F. This factor of 0.1 has been found by tests on actual installations to cover normal heat leakage losses through the insulation, and release of sensible heat from the mass of material. Even after 20 hr operation, the insulation mass does not reach equilibrium.

Air Range

Total **load in climb chamber** affecting air range is as follows in Btu per hr:

a. Half the leakage to chamber	5,040
b. Light, 500 watts	1,708
d. Six men in heated suits	8,280
e. 10 cfm dry air	1,800
Total	16,828

The fan should be selected for not more than 10 F air range through the climb chamber at 40,000 ft elevation. Try 6960 cfm. Weight of air circulated per minute at 5.54 in. Hg abs = 130 lb. The air range through the climb chamber is

$$\frac{16828 \text{ Btu/hr}}{60\times130\times.24}=9 \text{ F}$$

With air leaving climb chamber at −70 F it must therefore enter at −79 F.

The total theoretical air range must be based on the following loads, in Btu per hr:

a. Main chamber leakage	10,080
b. Light, 500 watts	1,708
c. Fan motor load	2,730
d. Six men in heated suits	8,280
e. 10 cfm dry air	1,800
Total	24,598

The total theoretical air range is

$$\frac{24.598 \text{ Btu/hr}}{60\times130\times.24}=13.1 \text{ F}$$

Hence the theoretical air temperature on the coils is (−79°)+(13.1°) = −65.9 F.

Surface Required

Assume −85 F refrigerant temperature.

Air on −65.9 F; Air off −79 F; Log MTD = 11.3.

Surface required in main chamber is

$$\frac{24{,}598 \text{ Btu/hr}}{11.3\times.5k}=4350 \text{ sq ft}$$

To hold −70 F in lock with −85 F refrigerant, surface required is

$$\frac{4160 \text{ Btu/hr}}{15\times.33}=833 \text{ sq ft}$$

The heat transfer coefficients are low, due to the low mass velocity of air at 40,000 ft elevation. Face velocity down through the large coil is approximately 300 ft per min.

For the total load of 2.52 tons of refrigeration a compound compression system, having a capacity of 2.64 tons at −85 F evaporating temperature and 110 F con-

densing temperature, was selected. The above selection is based on interstage liquid and gas cooling and on 100 F suction gas superheat at the entrance to the low stage machine.

A set of heat load curves may be used to establish the refrigeration rate required at the end of the specified period, as in **Fig. 3.** The curves are shown for three layers of Ferro-Therm; they also apply to 2 in. of cork.

Inside surface of climb chamber is 400 sq ft but due to bench, rails, parts, men, etc. a factor of 1.5 is used, giving $1.5 \times 400 = 600$ sq ft equivalent. From the curves, for a 12-min pull down from +70 to −70, or 140 F pull-down range, we get a rate of 11 tons per 1,000 sq ft or 6.6 for 600 sq ft.

This amount of refrigeration must be stored in the coils, refrigerant and shell at a temperature sufficiently below −70 F to give up the refrigeration to the climb chamber at a final climb chamber temperature of −70 F. Assume final temperature to be −85 for coils and −80 F for shell.

With no load in the climb chamber, fans and lock refrigeration cut off, the machines are operated until the cooling coils and refrigerant temperature are −95 F. At this time the shell temperature is assumed as −85 F.

Then:

Refrigeration stored in coils:
$8000\text{ lb} \times .116 \times (95\text{–}85) = 9{,}185$ Btu
Refrigeration stored in refrigerant:
$1000\text{ lb} \times (11.58 - 9.46) = 2{,}120$ Btu
Refrigeration stored in shell:
$13{,}300\text{ lb} \times .116 \times (85\text{-}80) = 7{,}725$ Btu
Total $= 19{,}030$ Btu $= 7.9$ tons

when dissipated in 12 min.

The actual pull-down time will be considerably less than 12 min, due to the safety in the curves when used in this manner, and also because the actual time element is a function of the rapid rate at which the finned coil can give up its refrigeration as compared to the rate at

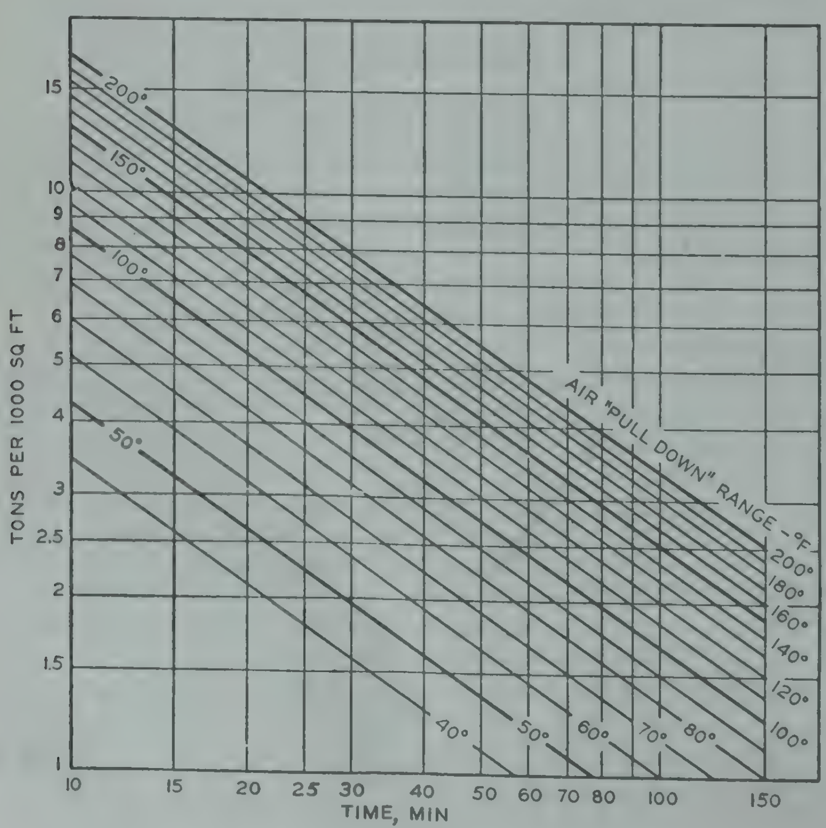
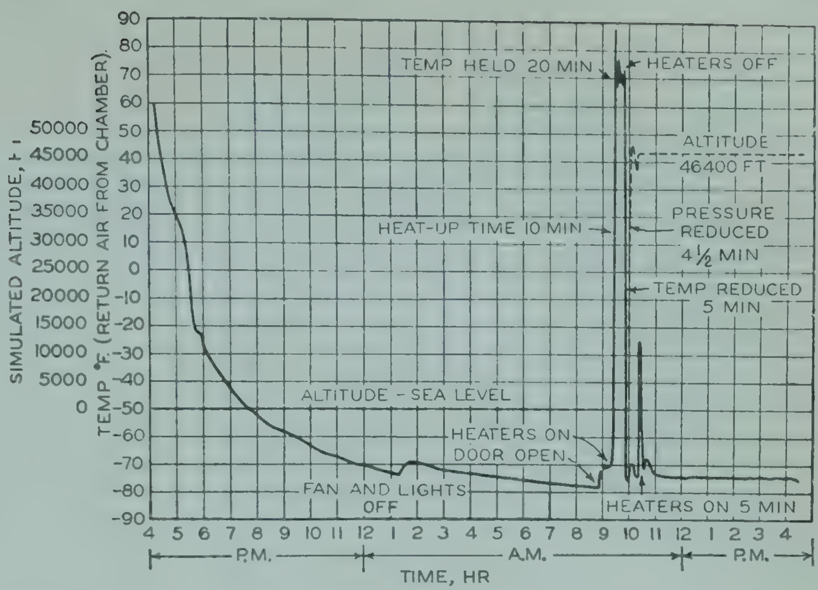


Fig. 3. Heat Load on Chamber with Ferro-Therm 20-Gage.

Fig. 4. Performance of Stratochamber—Pressure and Temperature.



which the relatively smaller amount of surface in the climb chamber can absorb it.

A compression system which can hold the total load as previously calculated at −70 F can readily lower the evaporator temperature from room temperature to −95 F in approximately 20 hr without any live load **(Fig. 4)**.

The solid line shows the return air temperature starting at 60 F at about 4:00 p.m. and pulled down to −79 F at about 9:00 a.m. the next day, or an elapsed time of about 17 hr. The climb chamber was then closed up and the electric heaters turned on to raise the climb chamber to about +70 F and held for 20 min.

The climb chamber dampers were then opened, the fans started up and the evacuating of the chamber started simultaneously. As noted on the chart, the altitude reading went from sea level to 46,400 ft in 4.5 min, while the temperature was reduced from +70 to −76 F in 5 min. About 10:00 a.m. some of the electric heaters were put on to show that the low temperature could be successfully counteracted and controlled. From 11:00 a.m. on the controls were set to hold −75 F temperature for 5 hr steadily.

Refrigerant Cycle

The low-stage compressor in this machine takes its suction gas from the surge drum under the coils, discharges it through a double-pipe gas cooler to the suction of the high-stage compressor, which in turn discharges it into the horizontal water-cooled condenser.

Liquid from the condenser flows to a Freon high-pressure float and a 10 in. ×3 ft flash-type liquid cooler, the gas from the cooler going to the high-stage suction and the liquid going to the annular space of a double-pipe oil still. The liquid is finally discharged from the annular space of the oil still through a second float to the surge drum under the coils.

A portion of the warm liquid from the condenser is tapped from the first float body to a thermal expansion valve, through which it is admitted to the annular space of the double-pipe gas cooler, and the resultant gas is piped into the suction line of the high-stage compressor.

A hermetically sealed liquid Freon pump circulates the refrigerant from the surge drum and through the coils, from which the liquid flows back to the surge drum.

A full size bypass connection is provided from the low-stage suction to the low-stage discharge. When starting to cool down from a warm start, this low-stage machine is not operated until the suction pressure falls below 15 lb gage. The high-stage compressor is motored for high suction pressures whereas the low-stage machine is not.

Of equal importance with the refrigerant cycle is the **oil cycle.** Oil levels must be properly maintained in both compressors.

The double-pipe oil still is supplied through a hand expansion valve, with liquid refrigerant from the discharge side of the refrigerant pump. This refrigerant contains a percentage of oil, and the mixture in passing through the inner tube of the still is heated so that most of the refrigerant is boiled out of the oil. The mixture of oil and gas passes on to the oil receiver at the low-stage compressor. From that point oil is supplied to the low-stage compressor through a crankcase float valve, this valve maintaining a level of oil in the crankcase. The refrigerant gas is piped from the oil receiver to the suction of the low-stage compressor.

Oil leaving the low-stage compressor is trapped out in the discharge line and piped to the oil receiver at the high-stage compressor. This compressor also has a crankcase float, fed from this receiver for maintaining its oil level, and the oil receiver is also piped into its suction line.

The discharge line from the high-stage compressor contains an oil separator with float drainer to return oil to the high-stage oil receiver.

A balancing line feeds oil from the high-stage oil receiver, through an Alco float switch and solenoid valve combination to maintain a fixed oil level in the low-stage oil receiver.

If you searched this chapter for something which was not found in it, please let the editors know.

SECTION VI

INDUSTRIAL APPLICATIONS OF REFRIGERATION

John G. Bergdoll, Jr., Associate Editor. Born 1898 in Philadelphia, Pa. Educated at Lehigh University, ME, 1920. Formerly, Draftsman, York Corp., 1920–27; Equipment Development Engr., 1927–35; Product Engr., 1935–38; Asst. Chief Engr., 1938; Chief Engr., 1939; Works Mgr., 1943; Vice President and Works Manager, 1949 to date.

Contributor to *Refrigerating Engineering;* Associate Editor Section VI and Author Chapter 45, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engrs.; Chairman, Standards Committee; Research Committee, Constitution Committee; Treasurer, 1945–47; Vice President, 1948–50; President, 1950–51.

Received ASRE Wolverine Award for outstanding ASRE publication for that year, 1943. At present, Vice President and Works Manager, York Corporation, York, Pa.

51. ICE MAKING PLANTS

THE modern manufacturing ice plant is a near replica of Pictet's designs of 1876,[1] Linde's disclosures of 1883,[2] and those of Raydt in 1886.[3] Ice cans in groups, raw water agitation, shell-and-tube evaporators, pipe coils, trunk evaporators, brine agitators, cranes and dumps—these devices are all old. A knowledge of the importance of refrigerant turbulence as a means of securing high heat transfer is disclosed in the records. Some of these early concepts were departed from for half a century until recent re-establishment.

Ice manufacture first developed along two lines: (1) Freezing distilled water ("Hygeia" system[5]) in cans, the water coming from the condensed exhaust of steam operated machinery, and (2) freezing river, pond or well water on two sides of large vertical plates, resulting in ice of a "crystal" clarity.[6]

Distilled water frozen in cans was mostly the product of breweries and storage warehouses, utilizing large volumes of steam. Its clarity depended upon treatment of the steam condensate, involving oil separation, charcoal and coke filtration and vigorous reboiling with steam to eliminate entrained air. These plants gave up to 10 and 12 tons of ice per ton of coal, if equipped with special distilling equipment and steam prime mover economies.[7]

ROBERT T. BRIZZOLARA, Author Chapter 51. Educated at Columbia University, ME, 1916. 2nd Lt. ASA, 1st World War; Field and Resident Engineer in design and construction of ice plants and cold storages for Ophuls and Hill, Inc., consulting engineers, until 1927; private consulting and advisory practice, serving in the designing, building, and operation of ice plants, cold storage warehouses, ice cream plants, breweries, and all food industrial operations, 1928 to date. Designed, built, and operated upward of 25 plants in the United States, Canada, and Cuba.

Author Chapter 9, 1939–40 Basic Volume and Chapter 46, 1946 Applications Volume, ASRE Data Books.

Member of the Amer. Soc. of Refrigerating Engineers since 1927; Professional Engineer, New York State, since 1924.

At present, Consultant, New York City.

In **plate plants,** blocks of ice weighing 4 to 5 tons were frozen 10 to 14 in. thick, frequently 12 ft deep and 20 ft wide. The refrigerated plates consisted of 1 and 1¼-in. continuous flat pipe coils, bent on 4-to 7-in. centers, clamped between light steel sheets. The ice built up on each side of the plates, reaching the desired thickness in 7 to 14 days. Frozen into the ice were hollow vertical lifting bars to be engaged with a crane. The ice was thawed free of the plates by circulating a warm brine, steam or "hot" ammonia gas within the coils after refrigeration was cut off. The ice was conveyed to a tilting table and laid flat; after the hollow lifting bars had been thawed free, the ice plate was sawed up.

The distilled water plant, as a rule, was usually less costly to build than plate plants. Where fuel costs were high, operating economies of manufacture favored the plate plant, and oil or gas engine operation was advantageously used.[9]

These plants were superseded by **"raw" water can plants** utilizing municipal water.[4,19] Ice clarity was secured by air agitation in loose cans, stationary can groups,[8] basket groups and finally the general type of today, cans grouped by rows, secured by a heavy steel top grid, with as many as thirty-four 300-lb cans in a single row.

Freezing Tank Design

Ice freezing tanks are usually constructed of ¼-in. **steel plate.** With the advent of improved welding, light sheet iron plate backed with lumber now has some consideration. Riveted construction of the tanks with metal-to-metal caulking is giving way to **welding.** The tank plate is usually butt welded, with a reinforcing welded band below. When the plate is lapped, the inside seam is solid welded and the underside 2-in. tack welded every 8 to 10 in., as necessary to resist the bending stresses encountered during tank lowering.

Tank depths must be such as to sub-

merge all can water below the brine level by 1 in.

A new development is to weld the plate assembly while set in place upon the cork insulation, leaving a ⅛-in. opening between the butted sheets. Beneath the open joint a 2-in. wide flat strap of ¼-in. steel is provided and the gap electric fill welded. This method offers construction economies at the slight risk of an undisclosed brine leak. The economy appears substantial; the stressing of the weld by tank lowering is avoided, and the ignition hazard of the insulation is slight.

Necessary tank **partitions** for directional flow of brine through the tank are usually of ⅜-in. plate, riveted or lock-nut bolted to riveted or welded angles on the tank bottom and sides. Tops or near tops of tanks and partitions are usually reinforced with 2½ or 3-in. angle iron to serve jointly as top alignment stiffening and support or rests for can grids or wood framework. Vertical angle stiffeners are resorted to for stiffening only in lighter weight than ¼-in. steel tanks. Bulging caused by hydraulic pressure is resisted by tie rods and external wood bracing.

Tank depths, usually 48 to 52 in. for 300-lb cans, become 60 in. for 400-lb cans. Tank widths and lengths rarely exceed 40 and 120 ft.

It is desirable to put clips on the bottom and sides of the inside tank, to provide for the attachment of 2×4-in. frame or iron **baffles.** The bottom wood framing provides jointly a baffle against short-circuiting of brine along the tank bottom beneath the cans, and a support for the cans when the tank is drained. The side framing prevents a flow of brine down the tank sides. Tank bottoms are preferably not provided with drain attachments because of their inaccessibility when inevitable corrosion occurs.

Brines

The usual brines in freezing tanks are **sodium chloride,** $NaCl$,[10] or **calcium chloride,** $CaCl_2$.[11] Salt brine is preferred because it costs less, will remain clear during years of operation, and is less injurious to hands and clothing of operators. Calcium brine is preferable where security against freezing is desired. A general rule is to use (salt) brine where the cooling surfaces will not be exposed to damage if freezing occurs, such as on pipe coil coolers, trunk evaporators or verti-flow coils. Calcium is preferred in shell tubular coolers, where the brine flows inside the tubes. Salt brine may be used with shell coolers if the density is properly maintained. Too dense a brine tends to "float" the cans and grids, and cause the cans to bulge inwards.

Chromate treatment against corrosion,[12] especially useful in protecting the galvanizing on ice cans, is universal. Ammonia leaks in brine are very destructive if this treatment has not been used. Such brine can be corrected of its ammonia absorption by aerating and hydrochloric acid treatment. Experience has disclosed that the need for replacing ammonia contaminated brines is very rare. Carbonate deposits from the brine upon ice cans can be controlled to a great extent by reducing the brine pH to slightly under 7 for a period of time. The pH value of brine is best maintained at between 7.2 and 8.5. Usual brine density limits for ice tanks are as follows:

Sodium chloride (salt brine) sp gr 1.143 to 1.17

Calcium chloride, sp gr 1.16 to 1.21.

Tank Insulation

With tanks operating on 10 to 15 F brine temperature, the usual tank bottom insulation consists of 4 or 5 in. of sheet cork. The insulation is applied in two layers, with all joints broken, and each layer applied in hot mopped asphalt. The top cork surfaces to contact the tank are similarly mopped, and all joints or crevices filled in with cork dust. Tank supporting **floors** are usually designed to carry a 350 to 400 lb per sq ft live load for 300-lb ice can tanks, and 425 to 500 lb per sq ft with 400-lb ice cans. Great care must be exercised in ascertaining that there is no water within 3 to 4 ft of the tank bottom. Frost may penetrate to a 4-ft depth below tanks with water present and cause disastrous movement of the tank. Drain tiles likewise freeze up if set too close to the tank bottom in a wet sub-surface.

The tank **sides** and **ends** are usually insulated with 10 to 12 in. of granulated cork between the tank and building brick or concrete walls. In some cases the side and

nd walls are of the parapet type, made of rick, concrete or 2×4-in. wood framing covered with a double layer of matched boards with waterproof paper between each layer. The external enclosure of the insulation must be damp-proofed with asphaltum or waterproof paper, to exclude penetration of external humid air. This is equally important for the curbing over the insulation around the tank.

Ice Cans

Ice cans can be secured in practically any desired size or shape from 25 to 400-lb capacity.[13,23,24] The usual commercial sizes are 11×22×49 to 52 in. in depth, plus ½ to 1 in. for can bottom insertion. A former popular size was 11½×22½×46 to 49 in., plus can bottom insertion. The cans are usually tapered 1 in. in their length, to facilitate dumping. This taper has been successfully reduced to ½ and even ¼ in. for 300-lb cans. The nominal weight of ice in 300-lb cans is 320 lb, and the block length for the narrower 1-in. tapered cans is about 43½ in. All excess weight over 300 lb is a nominal tare excess and is not in practice commonly credited to capacity ratings, but is used in low side and high side capacity calculations; 6¾ such blocks provide one ton of ice. The excess is for the purpose of offsetting dip tank, cutting and transportation shrinkages.

Cans are manufactured of galvanized sheet, fabricated by single or double riveting and soldering. Over the past decade, welded seam types have come into use, the welded seam being sprayed with tin. No. 16 gage sheet has given way to heavier No. 14 and even No. 13. Can bottoms are sometimes heavier than the sides, for added corrosion resistance and strength. The wide flat sides of the cans are generally center-grooved longitudinally to afford some stiffening and to take up metal slack of fabrication.

Cans bulge outwardly when out of the brine, and when filled with water; they bulge inwardly when set into the brine. The internal bulging is one influence of many tending to crack ice during freezing. No. 12 BWG cans bulge slightly.

Around the top of the can is a galvanized band ¼ in. by 1½ or 2 in., to provide stiffness and means for lifting and attaching to grids; ⅝-in. holes in these bands are used for hoisting single cans.

Devices for high pressure air agitation are provided by various means, such as a tube soldered in the inside corner, formed in the corner or attached externally. In low pressure air agitating systems the air is furnished by tubes suspended from above.

Freezing Tank Performance

The **time required** to freeze a given thickness of ice is determined first by the temperature of the ice freezing surface, in this case that of the brine. Most raw waters, treated or untreated, cannot be frozen without cracking at a temperature below 10 F. Distilled water can be frozen with temperature as low as 6 F.

Brine velocity has a marked influence on freezing time. It should not exceed about 35 ft per min. Brine movement is caused by the hydraulic gradient, best designed for about 1¼ to 1½ in. in the tank length. This permits submergence of water in the ice cans below the brine level. It is important to maintain brine movement, insuring a temperature as nearly uniform as possible. A variation of not more than ½ F is desirable, though 1 F is permissible.

Uniform rate of ice harvesting, on exact time schedule, is likewise necessary for maximum yield. The rate of ice freezing drops rapidly as the ice wall becomes thicker. An 11×22-in. can holding 320 lb of water in 12 F brine will make 280 lb of ice in 24 hr and consume 14 hr additional to freeze the 40-lb balance.

Where brine agitation is moderate, 15 to 25 ft per min, the time for freezing may be expressed thus:[37,38,39]

$$x = \frac{7a^2}{32 - t} \qquad \left(\text{see note on Fig. 1}\right)$$

Where x = freezing time for block, hr
a = thickness of ice cake, in.
t = temp. of brine, °F

This is derived from the expression

$$t = 32 - \frac{583.1a^2}{nw}$$

Where w = weight of the cake, lb
n = number of cans per ton of ice produced in 24 hr

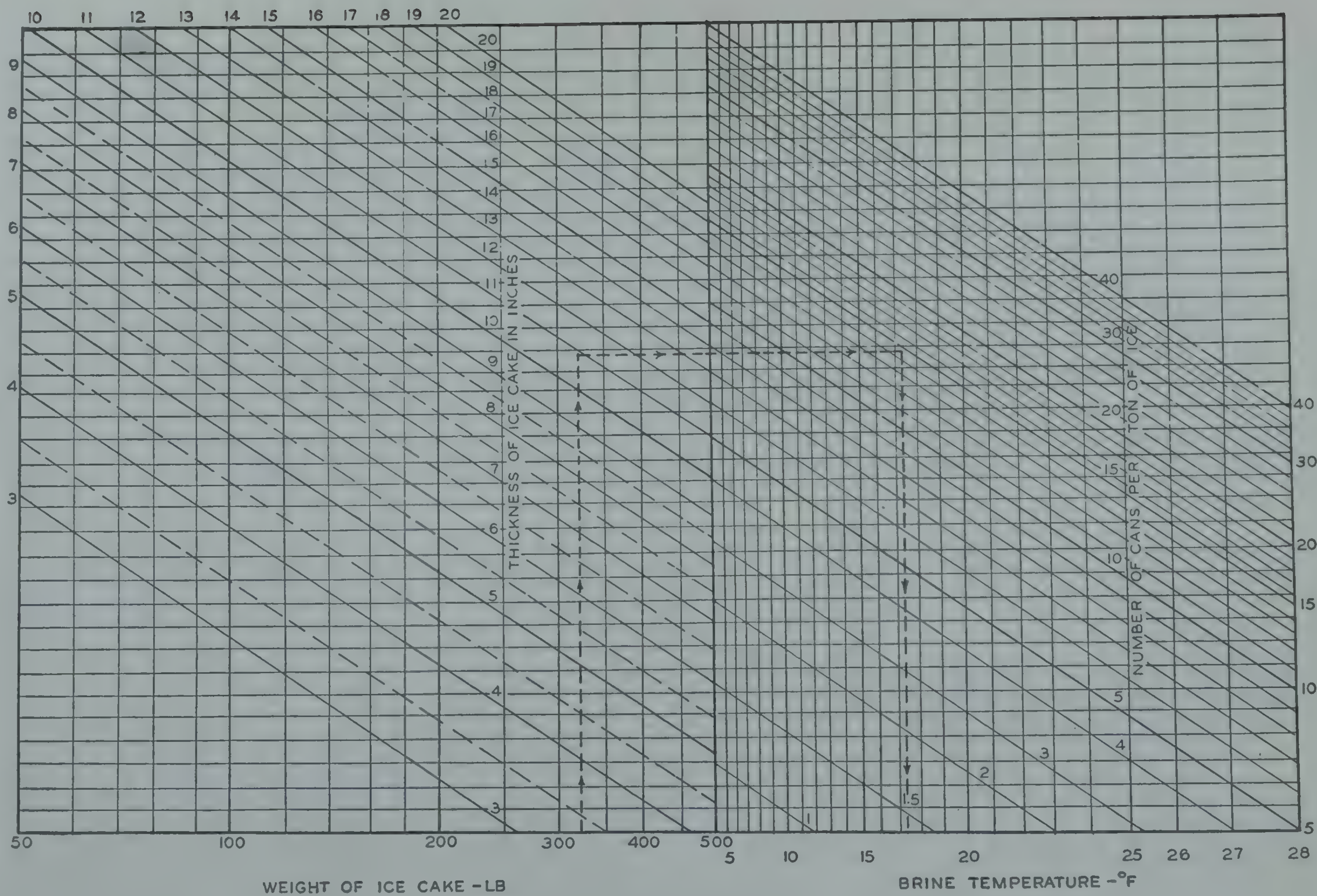


Fig. 1. Freezing Tank Performance.

t = Brine temperature, °F
w = Weight of ice cake in lb
a = Thickness of ice cake in inches
n = No. of cans per ton of ice produced per day

Note: The constant 7 in freezing time formula $x = 7a^2/32 - t$ reduces to 6.3 for 11″×22″ cans, with high

It is to be observed that with a given plant setup, the daily output is a function of the brine temperature only.

The number of cans per ton is the usual unit for rating **tank capacity.** It indicates the number of cans that are working in a tank to produce one ton of salable ice per 24-hr day, when ice is harvested uniformly. Cans per ton establishes the necessary brine temperature for a given daily output.[14,37,38]

Table 1 shows observed ice can performance when various brine temperatures are maintained in tanks, designed for 300-lb cans and all can water below the brine level. In **Fig. 1** Rasori has prepared a freezing tank performance chart for ready calculations of tank performance for various ice thicknesses.

Table 1. Normal Number of 300-lb Cans Required per Ton of Ice per Day
(Based on 30 ft per min brine velocity)

Average brine temp, °F	$11\frac{1}{2}\times22\frac{1}{2}$-in. can		11×22-in. can	
	Number	Freezing time, hr	Number	Freezing time, hr
22	22.5	81	21	75.6
20	19	68.4	18.0	64.8
18	16	57.6	15.5	55.8
16	14.5	52.2	13.5	48.6
15	13.5	48.6	12.5	45.0
14	12.5	45.0	11.5	41.4
13	12	43.2	11	39.6
12	11.5	41.4	10.5	37.8
11	11	39.6	10	36.0
10	10.5	37.8	9.5	34.2
9	10	36.0	9.0	32.4
8	9.5	34.2	8.5	30.6

Brine Cooling

The cooling of brine in ice tanks is accomplished by various kinds of **evaporators.** The latest types of tanks use one of the following: Open end shell-and-tube horizontal coolers, trunk coils, or vertiflow or raceway coils.[15,16,17,24] The older coil types appear to find acceptance in the new small tanks using low pressure refrigerants.

An enclosed cooler external to the tank may be used only when the brine is pumped from one end of the brine tank and discharged into an agitator at the opposite end. The thermal efficiency of this system is not equal to that of the usual design.

Typical freezing tank coil designs, until about 1925, had $1\frac{1}{4}$ or 2-in. black steel **pipe coils** arranged in single vertical stands running longitudinally and set up between each row of cans, along the tank sides and along the center partition. These designs possessed the advantage of having the evaporator surface adjacent to the freezing

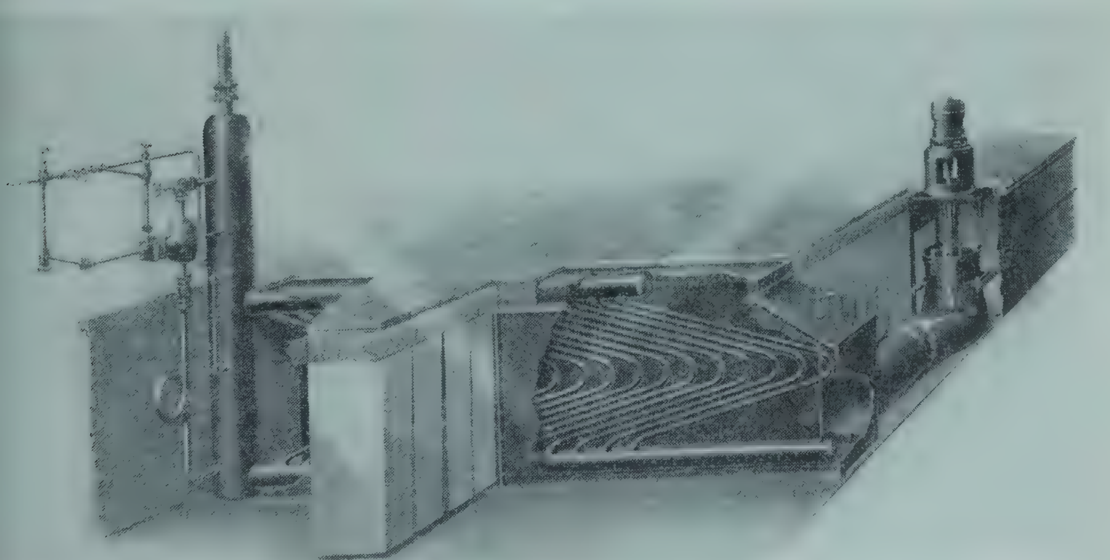


Fig. 2. Vertical Trunk Coils in Ice Freezing Tank.
Note also brine agitator and circulator and can group grids.

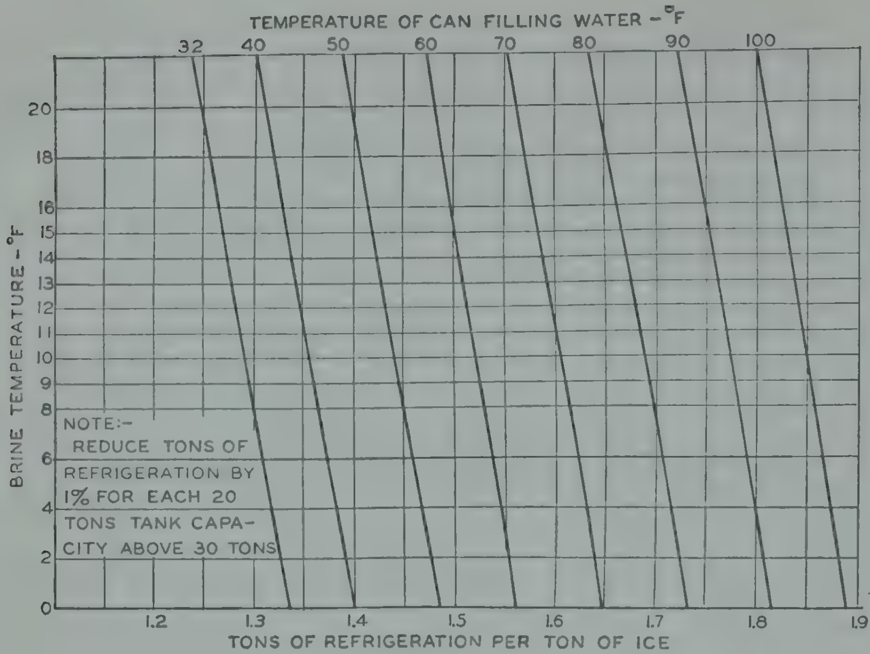


Fig. 3. Refrigeration Load Required to Produce Ice.
Note: Reduce tons of refrigeration by 1% for each 20 tons tank capacity above 30 tons.

ice cans, promoting a genuinely uniform brine temperature throughout the tank. Two-inch pipe coils were also arranged in various vertical and horizontal circuits, but $1\frac{1}{4}$-in. pipe was more generally used. Vertical stands 8 and 10 pipes high, containing 180 to 200 lin ft per ton of daily ice capacity was usual. More efficient tanks of the 10-pipe class used 240 to 310 lin ft of $1\frac{1}{4}$-in. pipe per ton of daily ice production.[18]

Open shell-and-tube coolers and trunk evaporators provide a large circulating brine volume in a single-pass operation. The cooling range at best does not exceed $\frac{1}{2}$ to 1 F, establishing the variability of brine temperature in the tank. Tanks of over 30 tons are usually divided into multiple sections so as to insure small temperature ranges. Brine velocities vary between 3 and 5 ft per sec through the shell cooler tubes, in order to keep the cooler diameter reasonable and agitation hp low. In shell-and-tube coolers, heat transfers of 60 to 80 Btu per sq ft per hr per °F may be procured, with brine temperature 5 or 6 F above suction temperature. These results call for about 50 sq ft of 2-in. tube surface per ton of daily ice making, with initial can water temperature of 70 F and a brine of 12 F.

In the development of tank coil designs, grouping pipe coils in tank bottom channels, beneath the cans, resulted in better heat transfer results, attaining heat transfer rates of 20 to 50 Btu per sq ft per hr per °F. The inaccessibility of these coils, despite their floor area economies, checked their extensive use.[2,3,19,21]

Short horizontal coils in raceways, in various arrangements, proved to be an improvement in some systems, with heat transfer rates of 20 to 35 Btu per sq ft per hr per °F secured. Later, there appeared the **trunk arrangement (Fig. 2)** of short V-bent pipe nested and welded into horizontal bottom and top pipe headers.[15,20,23] The ends of these headers terminated in a vertical shell accumulator serving as a vapor and liquid separator, while promoting rapid refrigerant recirculation through the bottom header, bent tubes and top header. The whole arrangement was enclosed in a tight brine raceway or trunk down the tank center, side or sides, giving good results. High brine velocity between the cans was possible with this design, by pitching the tank slightly in order to secure an hydraulic gradient. Successive rows of cans were set to follow this gradient. Heat transfer rates were 100 to 120 Btu per sq ft hr °F. This design established the importance of mass liquid circulation. It called for careful proportioning of header areas and lengths, else circulation

Table 2. Typical Operating Performance Data

(300-lb, 11 × 22-in. cans, with various types of ammonia evaporators: 10.5 cans per ton. Refrigerating load 1.6 tons per ton of ice, water at 70 F, brine, 12 F, condenser, 185 lb per sq in. gage)

Type of evaporator	Flooded vertical coil between can lanes, 240 ft $1\frac{1}{4}$-in. pipe	Bottom coil and vertical coil raceways, 180 ft $1\frac{1}{4}$-in. pipe	Horizontal, single-pass, shell-and-tube, 2-in. O.D. tubes	Enclosed bent pipe trunk, 70 ft $1\frac{1}{4}$-in. pipe
Surface per ton of ice daily output, sq ft	104	78	50	30.5
Brine velocity through cans, ft per min	15	20	25	30
Heat transfer, Btu per sq ft hr °F	20	30	75	120
Evap temp, °F and lb per sq in.	3.0 18.0	3.7 18.5	6.7 21.0	6.7 21.0
Required actual compressor displacement, cu ft per min per ton of ice	5.9	5.82	5.43	5.43

might fail and vapor locks occur in the headers. Oil removal from the system is best accomplished from these headers.

Refrigeration Requirements

The refrigeration required to produce a ton of ice in 24 hr varies with the initial can water temperature and the temperature of brine. Refrigeration includes removal of all sensible heat, latent heat of fusion, subcooling of ice, tank insulation losses, tank cover and radiation losses, agitation friction losses and losses involved in cooling the air for can water agitation. The refrigeration loads have been fairly well established from experience and are reliably shown in **Fig. 3,** which covers normally proportioned tanks of 30 to 100 tons daily capacity, including 7 to 8 percent excess weight, or tare, per commercial ton. Such tanks will contain 320 to 425-lb capacity ice cans and will be insulated with 5 in. of sheet cork or equivalent under the tank bottom, with not less than 10 in. of well packed dry granulated and regranulated cork or equivalent, around the tank sides and ends. The tank top and curbing will be of not less than 2-in. thick oak-and-pine covers, loosely fitted over the entire tank area. It is considered that the tank-supporting floor will be dry underneath, and of a prevailing temperature not exceeding 60 F. Determination of the evaporator temperature of corresponding suction pressure readily follows upon the establishment of tank load, brine temperature, evaporator surface area and heat transfer coefficient.

Table 2 illustrates the comparative operating performance of efficient 300-lb can tanks, using various types of ammonia evaporator systems.

Compressor economies resulting from improved evaporator performance are important, since the annual load factors on commercial ice plants range from 40 to 80 percent. To achieve 80 percent requires large ice storages for summer peaks.

Water and Refrigerant Forecooling

Forecooling will improve performance only in tanks containing pipe coil evaporators, and insofar as coils are better flooded when relieved of the vapor load of such forecooling in the tank. The vapor release occurring under high refrigerant-to-brine temperature differences, tends to expel liquid from the coils. To avoid this, more evaporator surface is utilized for drying and separation.

Ice can performance is not noticeably improved by forecooling, since the can surface is extensive and removal of the sensible heat from the water down to freezing is rapid; freezing time is primarily a function of brine temperature. The forecooling load removed from the tank evaporator can be closely approximated in Fig. 3 by

the difference between the refrigerating loads before and after forecooling.

Compressor power and size economy owing to water and liquid forecooling are reflected in all cases when this cooling is done at high back pressure with separate compressors from those on the tank evaporators. The usual higher back pressure adopted ranges between 40 and 50 lb per sq in. gage with water temperature ranging between 32 and 40 F. Under standard conditions of 20 and 185 lb per sq in. gage (ammonia), the ihp of 1.34 per ton of refrigeration drops to 0.82 per ton at 45 lb suction. Forecooling the water 30 F accounts for 15.5 percent of the refrigerating load; refrigerant forecooling of 40 F accounts for an additional 15.5 percent. These combined loads, 31 percent of the total load, effect considerable power economy and a comparable saving in necessary compressor capacity. At 20 lb and 185 lb per sq in. gage, the necessary real displacement required is 3.48 cu ft per min per ton and at 45 and 185 lb per sq in. gage, 2.05 cu ft per min per ton. The volumetric efficiency for a 2 percent clearance SAV compressor also rises from 80.5 percent at the 20 lb per sq in. gage suction to 85 percent at 45 lb suction.

Refrigerant liquid forecooling is usually accomplished in double-pipe stand coolers of 2-in. and 3-in. pipe or $1\frac{1}{4}$-in. and 2-in. pipe, with the high pressure liquid refrigerant flowing through the inner pipe.[17,22] With small operations, an ammonia coil in an outside pipe shell suffices. Still another method is to expand the high pressure liquid into a shell vessel or intermediate trap carried at high back pressure, conducting the expanded liquid of 45 lb to the ice tank evaporator. In this system the refrigerant liquid required for high back pressure water forecooling is cooled separately in a coil within the intermediate trap.

Water forecooling is accomplished in insulated still or agitated water storage tanks. The evaporator surface may take the form of close nested coils of galvanized full weight 2-in. pipe in circular unagitated tanks, or vertical flooded flat coil stands of $1\frac{1}{4}$-in. galvanized full weight steel pipe in agitated tanks.[22] The heat transfer rate rises from 10 Btu per sq ft hr °F in still tanks to 20 Btu per sq ft hr °F in agitated tanks. Cooled water is drained or pumped to the can fillers. The tanks are big enough to contain two to four times the volume of water required per hour.

All tank surfaces must be protected against steel contacting the water, preferably by galvanizing or surfacing with some odorless and tasteless asphaltic compound. All piping, flanges, bolts and nuts must be galvanized.

A preferable type of cooler is a shallow tank 18 to 30 in. deep in which are set up 2-in. pipe **Baudelot coolers,**[17,22,23,24] over which water is continuously pumped at the rate of 2 gal per min per ft of stand length. The tank and Baudelot cooler are in an insulated cabin with the circulating pump outside. The same circulating pump serves to fill the ice can filling tank. The heat transfer rate with simple expansion is 40 to 50 Btu per sq ft hr °F. With the Baudelot coolers full flooded from a level controlled accumulator above, connected with large, liberal, full sized vapor and liquid legs, a heat transfer up to 100 may be obtained. A modified Baudelot cooler consists of inclined pipes with a confined open water raceway beneath each pipe to facilitate high water velocity from end to end. Transfer rates above 100 are secured.

Brine Agitators

The purpose of so-called "agitation" is to circulate the brine so as to facilitate the conduction and transfer of heat. Originally, comparatively large propellers, 20 to 24 in. in diameter, mounted on horizontal shafts piercing the tank ends and belt-driven at low speeds, served this purpose. They later were considerably improved so as to maintain better brine circulation by means of proper baffle partitions in the tank.

With **horizontal agitators,** proper space must be provided for installing the pulley, drive, inspection and maintenance. **Vertical agitators** (Fig. 2), directly connected in a single assembly of motor, frame and propeller, are preferable because of their convenience for inspection and maintenance, as they can readily be lifted without any tank disturbances. When vertical agitators involve crane obstructions, they may be

operated by horizontal standard motors, set off to one side of the tank, driving the agitator by means of one-quarter turn V-belts.

Excess horsepower should be avoided in agitators because the hours of usage throughout the year represent a considerable power consumption over light and heavy load periods. The whole brine-circulating path must follow good hydraulic practice through elimination of excess friction heads occasioned by changes in volume velocity cross section. Lubricating, oil leakage and thrust bearing difficulties must be prevented in agitators. Means must be provided to prevent whirlpooling and drawing in air which cuts down their capacity as well as lowering the brine pH value. For maintaining a 1° temperature difference throughout the tank, the necessary brine volume circulated is based upon $7\frac{1}{2}$ Btu per gal per °F.

Can Lifts and Grids

In loose can tanks, 300 and 400-lb cans are kept in position by wood framework at the top on $14\frac{1}{2}$ to $15\frac{1}{2}$-in. × $24\frac{1}{2}$ to $25\frac{1}{2}$-in. centers. If the tank does not have coils between the cans, round steel **guide rods** between the cans are necessary to keep them vertical and to support the framework.[27]

Cans are grouped in multiple by means of deep **sections** of flat steel from 4 to 8 in. in depth and $\frac{1}{4}$ to $\frac{1}{2}$ in. thick.[2,23,27] The cans drop into transverse spaces between the long deep sections, with the ice can bands resting upon a provided shelf. The cans are held in position by square head rivets just over the can bands, or by a lightly riveted flat strip. The spacing of the cans in the grid is such as to provide desired brine flow areas between the cans, seldom exceeding 1 in. in width, except where transverse bars or plates are located between the grid bars to hold a pin for the lifting crane hook. These lifting pins are usually at intervals not more than eight cans wide. In one common design, using a light grid, the ice can bands rest directly upon the grid. The can bands are riveted together in groups and the end can of each group riveted to the transverse bars, also serving as the crane lift pin attachment.

Can grids are preferably hot-dipped galvanized. Their weight is important in preventing the cans from floating and tipping in the brine flow. Grids range in weight from 18 to 50 lb per can, the heavier the better.[23]

Wooden ice can **covers** rest directly over the grids, eliminating the need for supporting wood framework. The can covers, 2 to 3 in. thick and loosely fitted, are usually in groups of 3 to 6-can coverage. They also provide weight to hold the grids down in the brine.

Grids usually tie cans in groups of from four cans to half or full row tank width. Their use results in considerable labor saving in harvesting and filling. A spare can-grid set serves as a replacement for the group lifted out of the brine, thus quickly restoring the proper tank brine level.

Can **baskets** in lieu of grids are made of light angles and flat iron extending beneath the cans. They are rarely used, having been superseded by the simpler grid.

Air Agitation and Cores

Blowing air through cans filled with suitable raw water for freezing is necessary for making clear ice. The purpose of the air is to effect water agitation during freezing, which agitation assists in forming clear, pure water-ice crystals by rejecting the major volumes of the dissolved salts, and even color, into the unfrozen water core. The concentration of the salts becomes so high in the remaining unfrozen core, consisting of about 3 to 4 gal, that it is usual to pump out the core and replace it with fresh water, preferably cooled so that the core-enclosing ice surface will not melt and increase the freezing time.[23]

When **high pressure air** is used for agitation, it is compressed to about 25 to 30 lb per sq in. gage. A minimum of $\frac{1}{7}$ cu ft per min of free air is provided per can, and then cooled by means of water through double-pipe galvanized coolers or spray tanks.[15,28] The precooled air is in turn further cooled by passing it through ice water, by means of brine coils, or, more frequently, by passage through **dehydra-**

tors which consist of tanks containing brine-chilled coil surfaces. The water vapor in the air is frozen on these coils, and in due course the precooled air is switched over to another dehydrator shell which has been defrosted. Defrosting is accomplished by switching the warmer air back and forth from one dehydrator to the other, a process simplified by three-way cocks and valves on the air and brine lines. Condensate in all methods is eventually removed by hand draining or trap. The dehydrator is usually supplied with brine by means of a small circulating pump taking cold brine from and returning it to the ice tank.

The compressed air, after dehydration, is expanded by means of an automatic valve to about 15 to 18 lb per sq in. gage, which reduces its relative humidity. The air so treated is conducted by headers extending down the tank sides or centers. Air laterals, usually permanently attached to each grid, are readily connected into the main headers by means of a rubber tube and brass tapered friction fitting and check valve. The supply of air from the grid lateral to the can bottom is accomplished in a variety of ways;[27] in some instances by means of brass tubing to a fitting entering the can bottom or side; sometimes through a tube, which is an integral part of the can or is sweated in the can corner, terminating at the can bottom or even extending to the can center, by being sweated into a can bottom depression.

Air dehydrated in this manner will not freeze out its moisture content when contacting the brine while some flow is maintained. During the can lowering operation a temporary air blowing attachment must be maintained so that the can water cannot enter the air tubes, which would freeze shut quickly. The amount of air, about $\frac{1}{7}$ cu ft per min per can, is regulated by small orifice fittings in each can supply. These orifices are preferably kept above the brine level to prevent the tendency of ice crystals to close them and also to make them accessible for clearing an occasional stoppage by ice or foreign particles.[28]

In the **medium pressure** system the design is quite similar to the high pressure system in all details except that only one uniform pressure is carried in the system, namely 15 to 18 lb per sq in. gage. Since this air carries a higher humidity than the expanded cooled air of the high pressure system, the air volumes are increased to about $\frac{1}{5}$ cu ft per min per can and the regulating orifices correspondingly made larger. Otherwise the water in the air would freeze and block the air tubes.[28]

In the **low pressure system** of agitation, free air is compressed by means of rotary or centrifugal stage blowers to 2 lb per sq in. gage, or fractionally higher. One-half cu ft per min of air is provided per can.[28] The air is best taken from a warm engine room of high humidity, particularly in winter and cool months, in order to insure a heat content sufficiently high that it will not readily freeze out when passing through cool laterals and drop pipes in the cans. The blower air should enter through extensive surface filters. With this system, the air distribution must be liberally proportioned to insure maintaining not less than 2 lb pressure uniformly over the tank.

Air is usually supplied to individual cans by means of a removable lateral placed over the cans and lying in depressions provided in the grid transverse members. The air is introduced in the can by means of a $\frac{5}{16}$-in. drop tube extending to within 11 to 14 in. of the can bottom, and connected to the lateral with rubber tubing and fittings. Uniform air pressure is essential, and the drop tube must be located in the geometric center of the ice can. A swinging tube along the long axis is satisfactory, provided the open tube end swings through the center and cannot fix itself sidewise. A variety of means exists for accomplishing these ends.[27]

For high and medium pressure systems standard reciprocating type air compressors are used, as well as some wet rotary types. For low pressures, rotary blowers or centrifugal blowers are universally used.

A comparison of **horsepower requirements** for air agitation by the three methods described, covering a 60-ton, 300-lb, 720-can plant, is as follows:[35]

High pressure— 20-hp air compressor; 1-hp brine pump

Medium pressure—15-hp air compressor; 1-hp brine pump

Low pressure— 7½-hp blower

While the low pressure system has the least horsepower requirements, its refrigerating requirements may be greater because of the added volume of air chilled and blown through the can water. The low pressure system involves more work than the high pressure stationary tube type, because of the necessity of removing the air lateral and tubes with every harvest. The grid lateral, with the drop tubes attached, is usually lifted out at the time of pumping out the cores, and not replaced when the cores are refilled; this eliminates the need of thawing out the drop tubes if it is not desired that they should become frozen into the block.

Core pumps are preferably of the positive 15 to 30 gal per min piston type and not more than 1-hp. Rotary, self-priming centrifugal, and jet types of pumps are also sometimes used. The volume of water removed and temperature of replacing water is important. Core water is drawn from the cans by means of a 1-in. inside diam heavy hose and flattened tube. Core washing and filling with fresh water is from another similar hose, with suitable fittings and automatic valves for control. The rate of drawing and refilling cores should be not less than two cans per minute.

Cranes, Dip Tanks and Ice Dumps

Frozen ice cans in small tanks are lifted out by means of a wheeled portable stand straddling the can. A hand operated "crab" mounted thereon draws the frozen can up and out; it possesses a spiral differential diameter cable or chain drum to compensate for the increased effort required as the can loses its buoyancy and grows heavier. An improved method is a light four-wheel single-beam hand-pushed crane with the hand hoist suspended from it. A further improvement is an air lift or electric motor hoist, which can handle up to four cans satisfactorily. With larger tanks that go beyond the 50-ton-per-day capacity the powered travel type gains consideration.[15,23]

For can lifts of less than full row grouping a trolley supported hoist is powered for transverse travel on the bridge beam or truss, making for a three-motored crane. With full row lift the less costly two-motored crane is required, one for lifting and the other for travel. One-half ton electric hoists with not less than a ¾-hp motor are usual for one and two-can lifts. Bridge or travel motors are of ½ to 5-hp rating, depending upon crane weight and capacity. Trolley motors are of 1 to 3-hp capacity and hoist motors rarely exceed 7½ hp for the larger sizes.

Hoisting preferably takes place at speeds between 15 and 18 ft per min. Bridge speeds are about 75–100 ft per min and trolley speeds 150 ft per min.

The hoisting motor must be provided with a reliable heavy duty brake, and it is best to have a self-locking speed-changing mechanism in the event of brake or electrical failure. Standard designs of manufacture have been soundly developed to include these features. For safety, 110-volt electric service is preferable. Bridge or travel operation may or may not be provided with braking, according to the designs of various crane manufacturers. Trolley carriages similarly may or may not be braked.

Cranes are selected for the actual ice load to be lifted plus the weight of cans and grids. The hoisting ropes on a crane are either of the single-rope direct lift or single reeved type. Cans or groups are carried by the crane to the tank dump end where they are usually submerged under water in a **dip tank** and held until the ice block floats up in the can. Dip tank water is preferably held at not over 70 F in order to avoid ice stressing and cracking or undue melting. Dip tank displacement overflows from liberal weirs near the dip tank top.

After the ice thaws free from the cans they are raised and advanced to a dump. In one type of setup they are rested into a cradle supported on trunnions. This dump cradle consists of a front, bottom and side-end box or frame, suitably balanced. As the crane hooks are disengaged, an hydraulic cylinder for group lifts tips the dump quickly into position for the ice to slide out. In one- to four-can size dumps

the tipping and upending is usually manual. Quick tilting is necessary to prevent the ice from refreezing to the cans. The pitch for this dump and ice run need not be over 1 in. per ft to start, then diminishing to $\frac{1}{2}$ in.

The other common form of dump utilizes the crane for tipping the cans. The can group is rested off balance on a tilting table, and with the crane up against rail-stops, the can group tips over and is held back by the taut lowering cables. The tendency for some ice-blocks to refreeze to the cans, since the lowering is slow, necessitates resort to a steeper pitch of 3 in. per ft in the ice run, or the use of a two-speed motor for high speed lowering only.[23]

In some smaller operations the dip tank is dispensed with; thawing is effected by means of water jets mounted on the dump. A recent version of this spray design for limited group lift capacity consists of locking the group securely in the dump and upending it. After spraying, the ice drops down free a few inches to a stop. When the dump is upended by means of an hydraulic plunger, the ice slips around with it and out through an aperture.

All dumps, when free of ice, are righted again by hand, crane or hydraulic plungers, and again suspended from the crane hoist. In this position a lever-operated valve on an elevated **can filler** releases water from sectional tanks. Each ice can is filled automatically from 2-in. pipe spouts with the prescribed weight of water.

Can fillers are of open or closed type. Exact measuring of the water into each individual section of the open-type filler is accomplished by the overflow from one section to the next, the first section attached to the water supply line serving to operate a regulating float control valve of the balanced type. The float valve is locked shut upon operation of the can filling lever, and not released until the lever is returned to its original fill position. A long shaft across the filler tank, attached to the lever, operates dump valves on the bottom of each can filler section. This type of can filler calls for frequent adjustments to maintain uniform weights of water in each can.

In order to avoid floats and adjustments the fixed-size closed-tank pressure filler has been adopted. It consists of a series of small closed tanks or one large-diameter, single tank, solidly partitioned into individual can sections. While possibly assuring uniform weight per section, since the sections are solidly filled with water under pressure, the valve control mechanism is simple; individual float tank air vents are provided. Through the means of an internal inverted bucket weight control is permitted. Accessibility for cleaning and valve adjustments is sacrificed, to some degree, making the choice of types of can fillers one of individual preference.

Ice is sometimes dumped directly into the storage room in one to six-can dumps. For larger groups, however, it has proved advisable to dump it against the external storage wall. A transverse chain conveyor then drags it along the wall at a 5 to 15-ft per min speed to an aperture in the wall, permitting one cake at a time to slip into the storage. In this method large ice-passing doors are unnecessary, considerable storage space is saved, and water is not dragged along with the ice into the storage.[29] Means for timing each block of ice into a scoring machine are now available. Likewise devices for upending the ice automatically are available.

Water Treatments

Can water supplies treated or untreated are best filtered in open wood or steel pressure-type **sand** or **quartz filters.** All water lines must be galvanized. Periodic soaking and washing of the whole filtering and water line system with heavy soda ash treatment is a salutary method for cleaning and removing discoloration causes in the ice and serves for unknown reasons as an inhibitor against their recurrence for a time.

Water treatment to render water more suitable for ice quality freezing must frequently be resorted to. Undesirable water qualities can result in ice poor as to color, residues, and tendencies to shatter or crack. All water should be analyzed to determine the benefits of treatment.[15,29,30,36]

Refrigeration Equipment

SAV ammonia **compressors** enjoy the

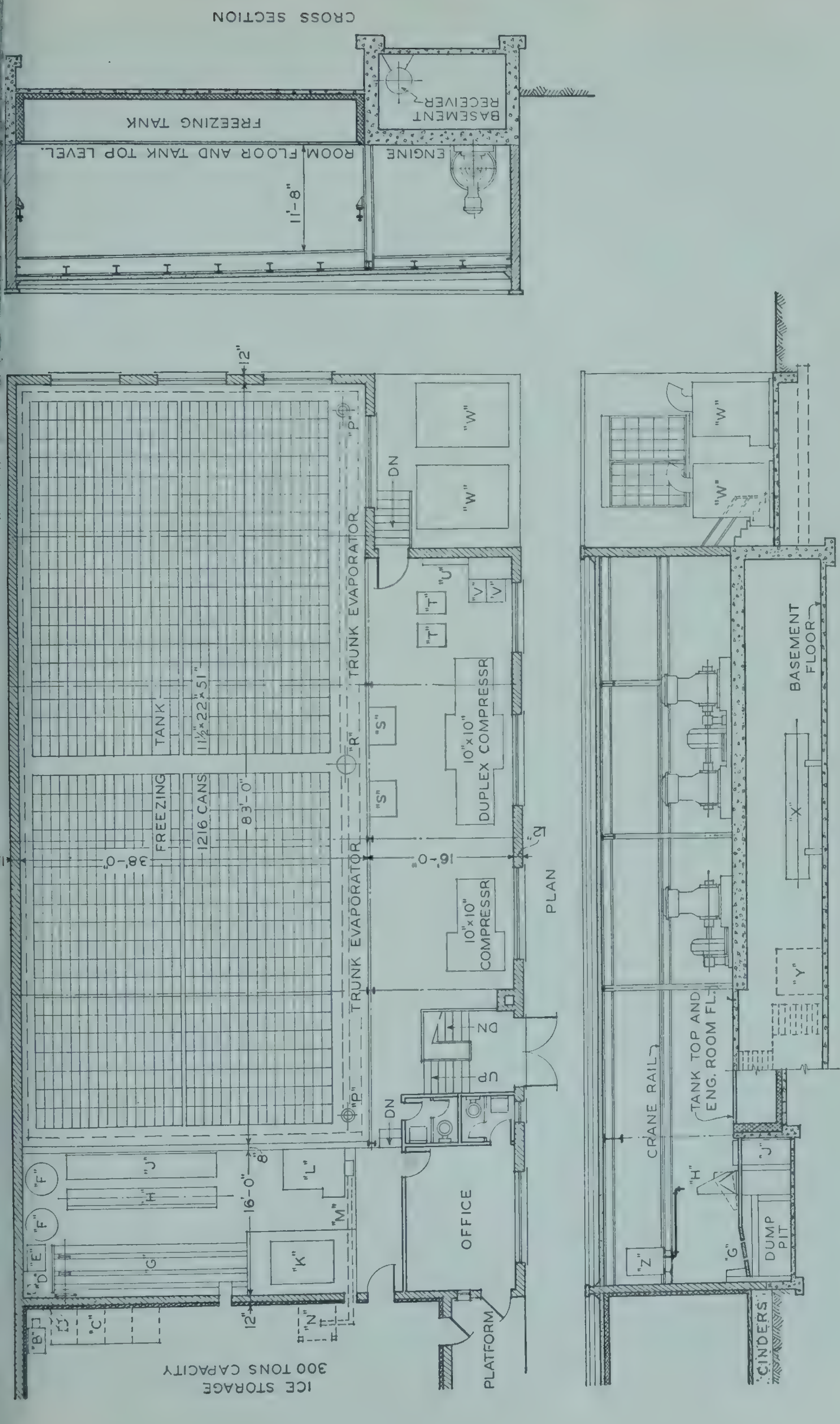


Fig. 4.

B—ice crusher
C—sized ice bin
D—snow chute
E—core pump
F—filters
G—dump conveyor
H—can dump
J—dip tank
K—scoring machine
L—ice cube machine
M—cube conveyor
N—cube bin
P—agitators
R—accumulator
S—blowers
T—M-G sets
U—panel board
V—starting panels
W—evaporative condensers
X—ammonia receiver
Y—heating boiler
Z—can filling tank

major preference in modern plants because they do not require as much operating attention, particularly on lubrication and shaft packing glands, as do horizontal types. They are less costly when under 75-ton unit sizes; they occupy less floor area and require minimum foundations. They possess no advantages over horizontal machines as to pumping efficiency, when both types are fitted with adequate valve areas.

Clearance and capacity control is an essential for economic performance. In lieu of this control the removal of the suction valves from one cylinder will effect a capacity control by that amount; mechanical balance is not affected and rarely electric balance in high speed units.

Condensers finding greatest usage in ice plants are shell-and-tube of both vertical open and horizontal multi-pass types. Next in order are tubular multi-shell, atmospheric pipe and double-pipe types. Shell-and-tube types are usually proportioned upon a basis of from 8 to 11 sq ft of surface per ton of refrigeration.[31]

Evaporative condensers are slowly coming into greater use, and they serve well when properly proportioned as to air volumes and surface. With their use, means must be provided to treat the water against scale formation and algae growth. They must be kept well purged and be connected in a manner to insure against their bottling up when arranged in parallel operation.[31] Inherent in them is the tendency to bottle up liquid.

Condensing water supplies are in general secured from **spray cooling ponds,** natural and fan draft **towers,** streams and shallow or deep wells. The use of wells is difficult to justify when the pumping power requirements exceed $\frac{1}{7}$ hp per ton of maximum daily ice production. At this point the need for spray ponds or towers is indicated.[33]

With spray ponds it appears most economical to operate on a 5 F cooling range with a 6 F approach to the prevailing summer wet bulb. With natural draft and fan towers, 7½ to 10 F cooling ranges, with a 3 to 4 F approach to the wet bulb, are most practical. The use of fan towers, preferably of the induced type, insures tower performance, whether of the filled or spray type, during the worst summer conditions of high humidity and air stillness. Practice indicates that a plant operates best with a single pump for summer duty and with one of half that capacity for winter service. With ponds or towers, pumping heads should not exceed 50 to 55 ft.

The operation of more than one centrifugal pump upon a common suction line is poor practice, since the resulting capacity is usually substantially less than the total indicated by the head-capacity pump characteristics. A Venturi meter is a sound investment.

Water capacity, refrigerating load and the water temperature rise through the condensers bear the approximate relationship of 30 gal degrees per ton of refrigeration. A determination of two of the three factors readily establishes the third:

$$\frac{(g)\,(R)}{30} = T$$

Where g = capacity of water circulated in gal per min

R = temperature difference between water on and off the condenser, °F

T = load in tons.

The constant 30 is based upon 250 Btu being abstracted from the condenser per ton of refrigeration. While an approximation reasonably close for average ice plant operating conditions, a closer determination of the heat abstracted by the condenser can be secured from the ammonia Mollier chart covering the actual operating pressures.[31]

Plant Economies

Much has been reported on ice plant performance. In general, well designed simple compression plants of 12 cans per ton, and 70 F initial can water, will provide ice at 50 kw hr per ton for low pressure air systems, as against 53 with high pressure systems. Winter operation reflects a similar comparison of 40 and 45 kw hr per ton. The maximum kw demand in low pressure plants will lie between 2.0 and 2.3, and for high pressure plants between 2.3 and 2.5. The power for auxiliaries in low pressure plants will be about 15 percent of the total

power consumption as against 19 percent for high pressure plants.

Power consumption will include a day storage of three to four times the maximum daily capacity, with some ice stacked or tiered. Power for scoring ice, cubing and sizing is not included.

Two back-pressure operations will effect additional economies of about 6 kw hr per ton in summer and 3 to 4 kw hr per ton in winter.

Compound operation, together with high back pressure operation, may effect economies over simple compression of 10 to 12 kw hr per ton for summer operation and 6 to 7 kw hr per ton in winter. The justification for compound compression complexities over simple compression is arrived at by comparisons involving all the known factors of plant size, investment, power rates, seasonal load factors and labor rates.

Ice Storages

Day storages should accommodate a full three days' ice production with ice held on end, based upon 13 sq ft per ton. When added storage is required, provisions for stacking on edge up to six cakes high, with a portable tiering machine, is practicable. The minimum storage height to allow below ceiling coils is 7 ft.

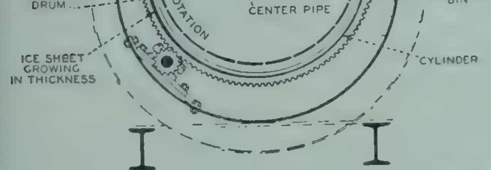


Fig. 5. Section Showing Flakice Principle.

Where more storage is desirable, **season storages** are built adjacent to the day storage at the same or lower floor level. The day storage in such instance can be halved in size. For best operation season storages should be limited to about a 30-ft storage height. Whole ice cakes are stored on edge with the first layer held off the floor, preferably on 3 × 6-in. timbers on edge, two under each ice cake. This arrangement promotes cold air circulation over the floor. Ice is stored at least 8 in. from the side walls, cake to cake whether scored or unscored. If the floor area is extensive, it is

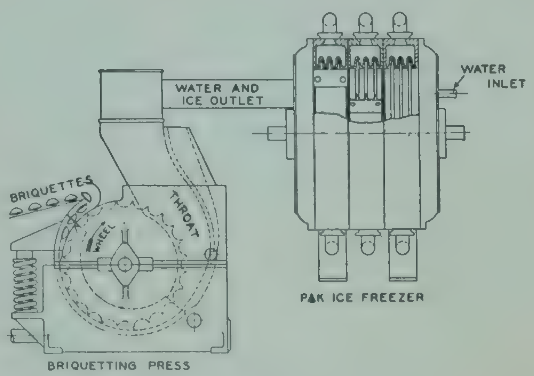


Fig. 6. Pakice Machine (Right) and Briquette Maker.

practical to allow a spacing lane of at least 8 in. for air circulation on the column center line up through the stack. Ice is preferably stacked to such a height as to leave a clearance of not less than 3 ft under the ceiling coils. The storage capacity of a room is based on 50 sq ft per ton for the entire room content volume. This allowance usually provides ample air circulating clearances, elevator area and space for cooling coils. Season storage facilities are in most every instance more costly than manufacturing facilities for a like tonnage.

Insulation in day storages and season storages is based upon maintaining a 24 to 28 F room temperature.

Two-inch direct expansion piping on 10 and 12-in. centers is usual for cooling. With suction pressure of 22 lb per sq in. gage ammonia, 1 ft of 2-in. pipe per 18 to 22 cu ft of storage volume is usual. The coils are divided over the ceiling area in flat banks with one expansion valve for 800 to 1200 lineal ft of coil. Control of the coils by thermostatic expansion valves is desirable. It is advisable to keep the coils within 30 in. of the roof deck in order to prevent ceiling sweat and drip. In very large season storages, 2,000 to 8,000-ton capacity, the coils frequently are arranged in double tiers with 8 to 10-pipe-high coils along the walls near the ceiling. In some arrangements the

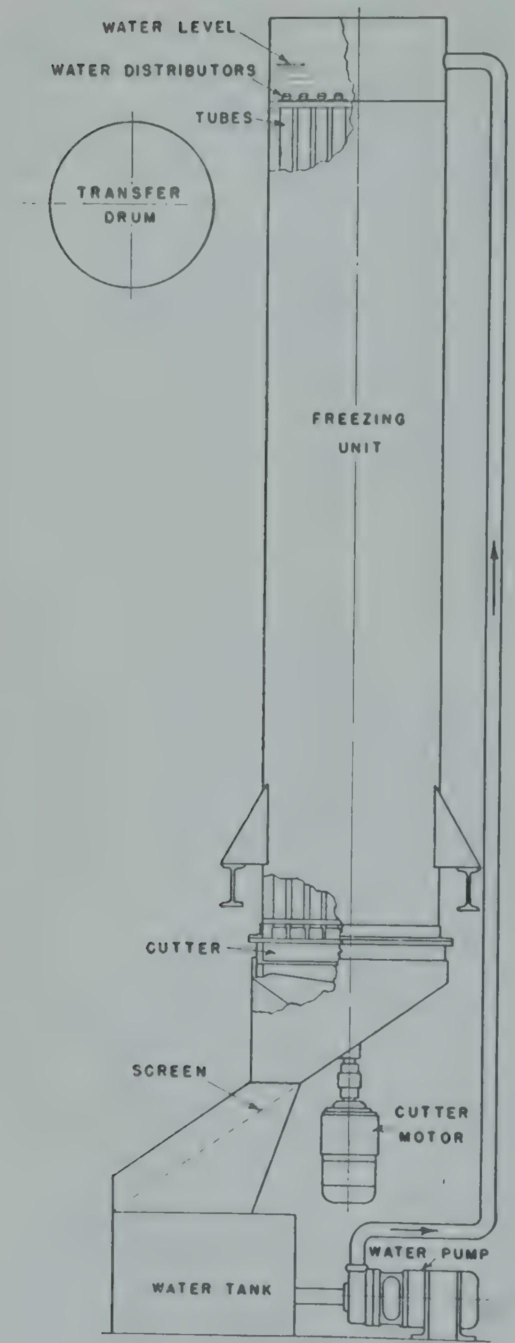


Fig. 7. Tube Ice Machine.

ceiling coils are connected to a horizontal large diameter accumulator for flooded float valve controlled operation.

It is advisable to provide "hot" gas connections to all storage coils for defrosting. A ½-in. line from the top of the receiver will suffice in most instances. A refrigerant charging connection in the storage room liquid feed line proves very convenient.

When the storage suction is on the main plant suction, it is necessary to hold the plant suction down to insure proper storage refrigeration. This may be an expensive operation at times when ice can conveniently be made at high suctions, or when the plant compressors could otherwise be shut down. For these reasons an independent condensing unit is a good investment. With an independent unit, a single coil or large accumulator type evaporator, the high side float control is nearly ideal.

In large day storages the use of a chain conveyor to carry stored ice to the loading platform is imperative. In season storages a 5 to 8-cake capacity freight elevator has advantages over the usual fast gig elevator. While a freight elevator is not so fast, one man can handle the whole operation of elevating, stacking and unstacking. Such an elevator can be relied upon to handle 50 tons per 8-hr man day.

The doors into ice storages should be as few and small as possible. One entrance door from the platform of 42-in. width is advisable; it should be kept locked except when machinery is being passed through. One ice-passing door for a 50- to 60-ton daily capacity plant is usually adequate. An 18-in.×48-in. door, of vestibule type, is becoming general.

Ice Utilities

The modern character of the ice business involves other ice operations aside from the manufacture of block ice; scoring machines, cubing machines, sizing machines and packaging machines for automatic vending stations are recent developments which are extending rapidly and are worthy of careful consideration. Such operations call for an enlargement of usual day storages.[34] Stacking is costly.

The definite trend of ice sales today is in small sizes—both cubes and sized ice. Sized ice lends itself particularly well for vegetable preservation by direct contact. In many localities 50–60% of ice sales is in cubes and sized ice. The trend is definitely to the packaging of this ice in "wet strength" paper bags besides other containers of canvas, barrels, wooden tubs and boxes. Health authorities are legislating to bring about a compulsion in the use of non-returnable

containers. These paper containers have various capacities—7½, 10, 30, 50 and 100 lb. The smaller sizes are used in automatic coin vending machines, located in refrigerated boxes.

Dairies are adopting canvas ⅜ in. cotton mesh bags of 20 lb crushed ice capacity for cooling by drippage stacked milk cases in trucks. This meets with modern Board of Health favor and avoids square bottle breakage. The bags are regularly laundered.

This trend for packaged ice calls for considerable additional day storage by some 30 to 60%.

Scoring machines, which mark the ice block with 1 to 1½-in. deep saw cuts of exact weights of 25, 50 and 100 lb, are offered in a variety of designs. In general they can score about 5 blocks per min. In the typical day storage these machines have the disadvantage of occupying too much space and entailing problems of snow removal.

The desirable location for a scoring machine appears to be in the ice tank room close to the ice dump, with an ice chain conveyor feeding the machine, from whence the ice slides down a chute into the storage. However, one difficulty with this location is the machines are inclined to rust.

Cubing machines cutting ice into 1½-in. cubes are of a variety of types; they are best located outside the storage room, delivering the cubes by belt conveyor into an overhead bin in the storage. The problem of snow removal is eliminated in this arrangement. Cubing machines are procurable to handle block sizes of 25, 50, 100 lb and whole 300-lb cakes.

Sizing machines, which have come into increasing general use, consist of an ice

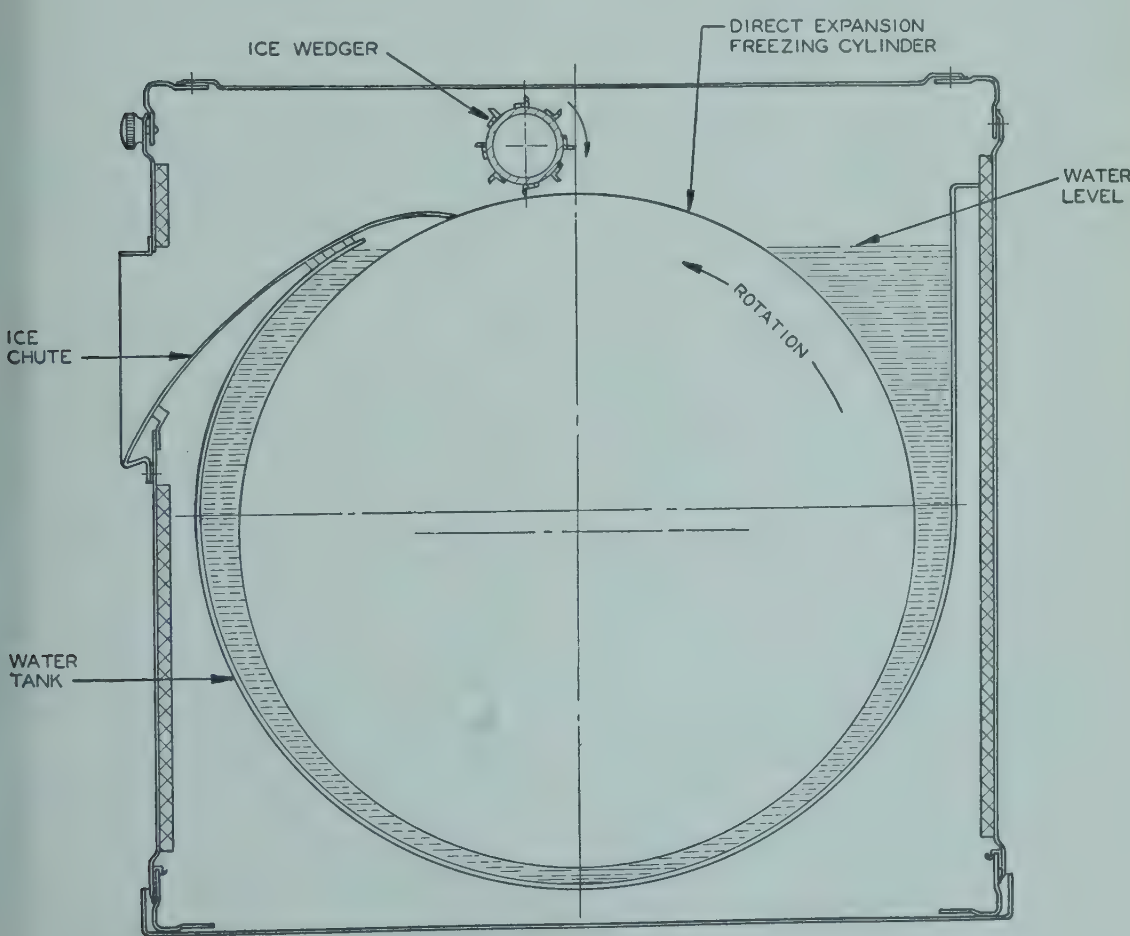


Fig. 8. Flakice-York DER Type.

crusher delivering ice into an overhead rotating screen, which screens the broken pieces into bins containing desired sizes. Problems presented in this operation are those of disposing of "fines" and keeping losses due to excess breakage to a minimum. Means are now available for weighing and filling paper bags and other ice containers with sized ice and cubes.

Packaged ice is ice cut into 25 and 50-lb pieces by saw or electric resistance hot wires, and then automatically wrapped and sealed in suitable paper wrapping. In turn these packages must be kept refrigerated and dry while delivered to automatic vending machines over a scattered territory. These boxes or stations must be kept refrigerated continuously, for any dampness of the package renders the vending apparatus inoperative. Automatic vending of packaged ice, cubes and sized ice, now well started, runs the whole gamut of refrigeration, through production, processing, transportation and selling.

Vegetable icing is accomplished through the means of portable **slingers,** which are combination units of a block ice crusher and a crude centrifugal pump hurling this ice through 4 in. 30 ft length rubber or metal hose and spraying this ice over vegetable products loaded in railroad cars and in trucks.

The methods for handling and processing ice have not enjoyed as much technological progress as that spent on other products, despite the universal distribution of ice reaching 50,000,000 tons per year and representing 80 to 85,000,000 tons of refrigeration actually produced.

Automatic machines for the manufacture of ice other than by the can or plate process have reached a proven state of development. In general they employ one of four general methods of removing ice from surfaces to which it has been frozen, by either direct expansion or cold brine. Separation from a flexible surface (the Flakice flexible brine chilled cylinder type of machine, **Fig. 5**); scraping the ice crystals from a wet direct expansion chilled surface and pressing the slush into briquettes (the Pakice system, **Fig. 6**); "hot" vapor heating the surface to release ice frozen by direct expansion in 2 in. tubes (the Vogt Tube Ice Machine, see **Fig. 7**); and wedging the ice from a direct expansion refrigerated drum (the Flakice-York DER type, see **Fig. 8**).

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If you searched this chapter for something which was not found in it, please let the editors know.

52. SKATING RINKS

THE term ice skating rink usually refers to an enclosed sheet of ice artificially made for skating purposes or to the building containing such a rink. The sheet of ice is made from water frozen either by the **direct process** of refrigeration with refrigerant flowing in pipes or by the **indirect process** using brine.

This chapter will be confined to the design and construction of the (1) rink floor piping, (2) the floor itself, and (3) refrigeration equipment.

Piping and Floor Design and Construction

There is a very definite type of floor construction best suited for each particular installation, as required to meet the conditions of initial cost, upkeep, operation and depreciation and, for the first necessity, a proper ice surface.

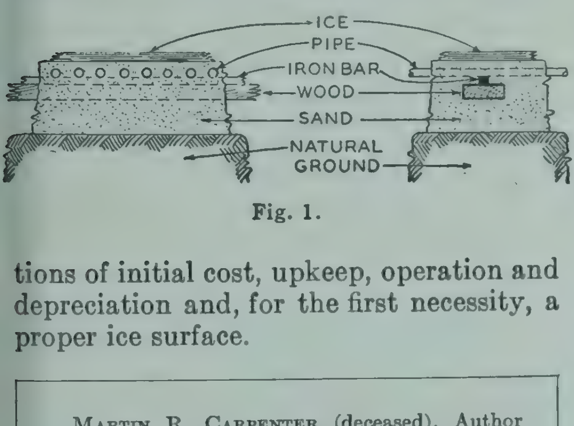

Fig. 1.

MARTIN R. CARPENTER (deceased), Author Chapter 52. Engineer and inventor, a pioneer in the refrigeration industry, he developed the first shell type brine cooler used in modern refrigeration.

He was associated in his earlier professional years with the A. H. Barbor Company; later as Chief Engineer with the Brunswick Ice Machine Company of New Brunswick, N.J., and in the same capacity with the Triumph Ice Machine Company of Cincinnati, Ohio.

Establishing a consulting engineering office, he specialized in the construction of ice rink floors, inventing and developing the Monolithic Concrete Floating Floor and Piping System, which furnishes a permanent all-purpose floor, thus providing for profitable operation of rinks the year around. He also designed the Carpenter planer for resurfacing the ice floor and other ice tools.

Many technical papers and articles written by him appeared in journals and trade papers, his final contribution being Chapter 47 of the 1946 Applications Volume of the ASRE Data Books.

He was a charter member of the American Society of Refrigerating Engineers.

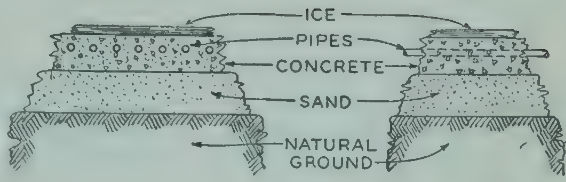

Fig. 2.

Ice floors vary in **size** from small areas, about 400 sq ft, suitable for private figure skating, to rinks of 15,000 to 16,000 sq ft, for hockey and public skating. Larger sizes are sometimes made for public skating. While there is no definite size for hockey rinks, that considered most suitable is about 85 ft wide and 185 to 200 ft long; the floor must be surrounded with a solid barrier not less than 3 ft 8 in. high. Curling rinks require a space 12 ft wide and 120 ft long. A number of such rinks can be set up in any desired part of a public or hockey rink. The size of ice floors referred to above designates the actual ice surface.

Many rink installations have floor pipes laid on a bed of sand on which the ice sheet is formed with no provision for the use of the area when there is no ice. In preparing an ice floor with this type of construction, it is necessary to saturate the sand with water, freeze it solidly, and then gradually build up the ice sheet to required thickness, usually about $1\frac{1}{2}$ to 2 in. This process generally takes from two to three days before the surface is suitable for skating. Such a rink floor, the general construction of which (**Fig. 1**) is the cheapest in initial cost, is as efficient in operation as any other; it is also easy to repair or to replace defective floor piping. Its chief disadvantages are its rapid disintegration due to corrosion of the floor pipe, its inability to maintain a constant floor level without annual labor expense and its disutility as a floor when the ice is removed.

In order to provide means for using the building and floor area for other purposes when the ice is removed, most installations include a permanent floor, often termed

all-purpose floor. Such floors are constructed with the refrigerating pipes imbedded in the body of the floor. When the ice sheet is maintained constantly throughout a skating season, and the bare floor used for other purposes during the off-skating season only, a floor supported directly on the ground is most suitable and also the least expensive initially.

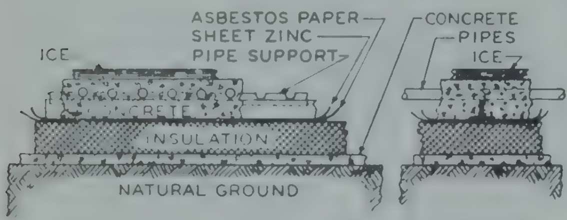

Fig. 3. Carpenter Floor—Type "B" Insulated.

This type of floor, shown in **Fig. 2,** may have a float finish, a troweled cement top, or a fine terrazzo finish. When properly designed and constructed, such a floor will withstand loads as well as the average street pavement. It will protect the floor pipes from corrosion, maintain a continuous level, and last indefinitely. Two floors of this type, installed at the U. S. Military Academy, West Point, N. Y., and Playland, Rye, N. Y., have been in continuous seasonal use for 15 years without any signs of failure either of the floor or piping.

A common demand is for building structures suitable for diversified activities such as rodeos, circuses, athletic events, roller skating and conventions, requiring suitable floors which may also be used for ice skating. This demand has been met by a floor construction which provides a bare floor, or an ice floor, on a few hours' notice. To make a quick change from an ice sheet involving a temperature of about 15 to 20 F in the mass under the ice, to a floor temperature of about 70 F, or vice versa, requires an addition or extraction of many units of heat in a few hours' time. To limit this mass of material to be heated or cooled, it is necessary to install a layer of **thermal insulation** between the supporting bed of concrete and the floor slab. **Figs. 3** and **4** illustrate the Carpenter and the Funk floor constructions, as used in many of the modern rinks.

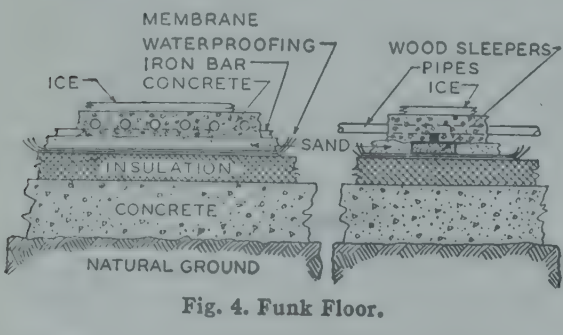

Fig. 4. Funk Floor.

The use of thermal insulation under an ice floor saves refrigeration, but possibly only to a limited extent and in the first few days of operation. In cases where the floor is supported as part of a building, above a floor slab, it is advisable to install sufficient insulation to prevent condensation on the floor or any ceiling below, and to minimize the heat load on the ice floor.

All of these types of ice floors are applicable to either outdoor or indoor rinks.

In planning a permanent all-purpose floor, the following necessary conditions should be recognized.

1. The floor should be capable of sustaining concentrated loads equal to those imposed on a substantial street pavement.
2. It should withstand expansion and contraction without breaking or cracking.
3. It should protect the floor pipes from exposure to moisture or air.
4. The entire body of the floor should have uniform composition and expansibility and be free of all voids in the body of the concrete.
5. The composition of the floor should stand repeated freezing and thawing without deleterious effects, and have a high rate of thermal conductivity.
6. The entire floor should remain perfectly level and should have a surface suitable for any use.

There are other types of floor construction, some illustrated here, as a rule designed to meet some special situation. The **pan rink** installed on thermal insulation,

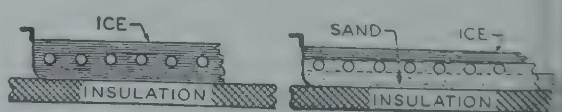

Fig. 5. Pan Rink Installed on Thermal Insulation.

as illustrated in **Fig. 5**, is often used in small sheets of ice on stages or floors of night clubs. A series of pipe coils is placed on wooden strips in the bottom of the pan, and submerged in shallow water. Installations have been made by laying water-

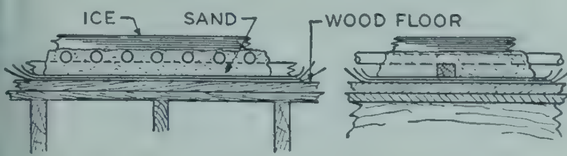

Fig. 6. Another Type of Pan Rink.

proofed paper on top of a wooden floor, on which a membraned waterproofing was applied and the floor pipe with sand covering laid thereon, as in **Fig. 6.** With this type of construction, floor pipes are likely to require frequent renewal, the water-proofing and sand have to be changed, and no thermal protection is provided.

All rink construction thus far described has employed commercial piping or tubing to distribute the refrigerating effect. Other methods have been employed such as the Vetter System shown in **Fig. 7,** which utilizes a steel sheet to form a surface on which to freeze the ice sheet.

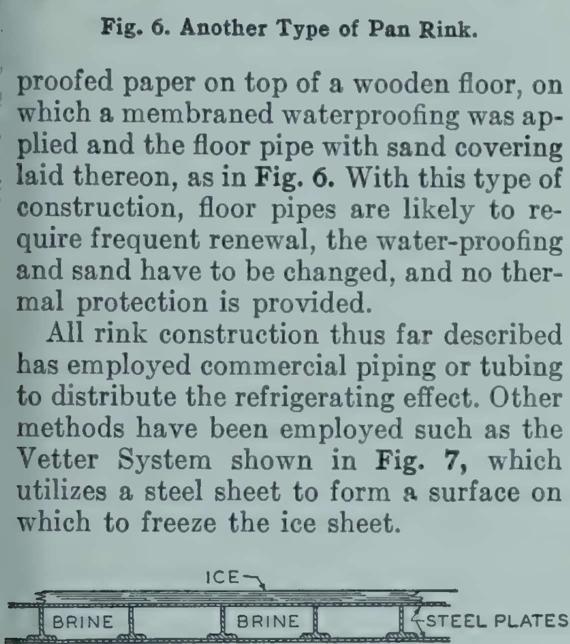

Fig. 7. Vetter Ice Floor.

Another system known as the Strite System, shown in **Fig. 8,** has been used in connection with a swimming pool in New York City in which brine of the proper temperature is sprayed on the under side of a continuous steel plate floor with the usual shallow covering of ice. Other systems of rink floors and stages are shown in **Fig. 9.**

Floor piping generally used for skating rinks is of 1 in. or 1¼ in. size, depending upon the preference of the designer. The same may be said relative to the spacing of the pipes, which varies from 3 to 6 in. on centers. Steel pipe is usually installed because of its lower initial cost per linear foot, without taking into account the potential freedom of wrought iron from corrosion.

The greatest hazard to the long life of a rink floor is the possible failure of thé floor piping, due to external corrosion, which is bound to occur when the outer surface of the pipe is in contact with moisture and

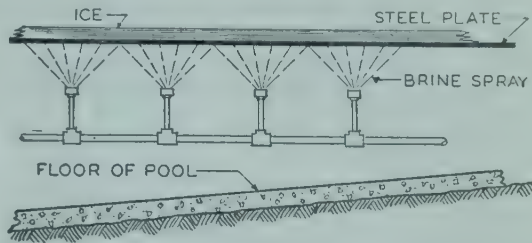

Fig. 8. Strite System for Swimming Pools.

air, especially in the presence of salt air. If the piping is thoroughly imbedded and bonded to the concrete, its life may be extended indefinitely.

Experience has proved that floor piping laid on 4-in. centers, especially when imbedded in concrete, gives the most satisfactory results in temperature distribution and heat absorption. Only where the most extreme conditions are anticipated, will it be necessary to use shorter intervals. In general 1-in. pipe laid on 4-in. centers will provide ample transmission surface to bal-

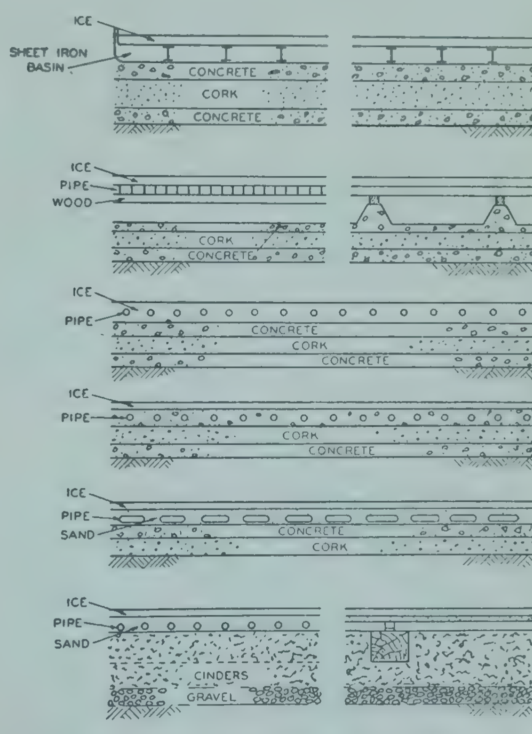

Fig. 9. Various Cross Sections of Rink Floors and Foundations.

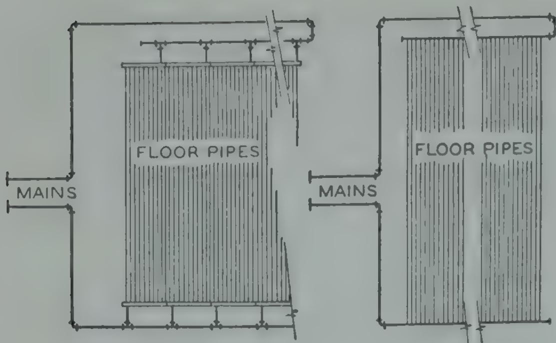

Fig. 10. Balanced Flow System of Distribution.

ance the capacity of the refrigerating machinery. This procedure may cause a greater range in brine temperature, however, than is allowable for ice temperature requirements, unless the quantity of brine circulated is sufficient to limit the temperature range within 3 F. Therefore, the size of the pipe should be determined by the length of pipe run between inlet and outlet headers, based on the quantity of brine to be circulated to hold the temperature range as stated. One-inch pipe is usually suitable for runs up to 130 lin ft but $1\frac{1}{4}$-in. pipe should be used for longer ones.

The arrangement of **brine mains and connections** from the mains, of both inlet and outlet ends of the floor piping, will determine the efficiency of the entire floor piping system. It is essential that every foot of floor piping in the system be maintained at nearly the same temperature, making due allowance for the necessary slight rise in temperature as the brine flow traverses the rink. When a system for reversing the direction of the brine flow is installed, this difference of temperature can be largely overcome. Every floor pipe should receive and convey the same amount of brine directly from the supply main and discharge it directly into the return brine main.

From the foregoing, it will be apparent that equal distribution is an essential requirement. Many methods or designs have been used in an attempt to secure equal distribution, but not all have been successful. Some designers favor supplying brine under pressure in a main, connected to each floor pipe with some type of control valve or reduced section. This method is likely to prove a disappointment.

The balanced flow system, on the other hand, has proved much better. With this flow system, shown diagrammatically in **Fig. 10,** there is no restriction to brine flow at any point, and the distribution is uniform regardless of the quantity of brine circulated. The loss in brine pressure is little, the friction head generally running not more than 5 to 6 lb per sq in. No valves or other means of throttling the brine flow are required at any point, and no heating of brine occurs in pumping, on account of the restricted flow.

Pipe trenches are necessary in the design of a complete rink. While they may increase the initial cost of the installation, they will, in the long run, save more than their cost and possibly be a means of preventing what might otherwise have been a total failure of the floor piping system. Pipe trenches make it possible to clean pipes which have become stopped up, and provide necessary space for mains, manifolds, and flexible connections to floor pipes, with access for cleaning and painting. The location and size of such trenches depend largely on the design of connections between mains and floor pipes. They may be located on opposite sides or opposite ends of the rink floor, or may be on one side only, in which case both inlet and outlet mains would be in the same trench.

In designing the connections between floor pipes and brine mains, it is necessary to provide some **means for discharging air** trapped in floor pipes. Small air cocks have been installed in many rinks for this purpose, but are impracticable from an operating standpoint. The ideal method is to locate the outlet main and connections higher than the floor pipes, as illustrated in **Fig. 11.**

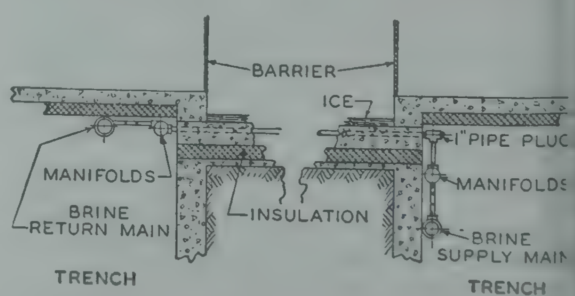

Fig. 11. Carpenter Monolithic Floor and Piping System; Side Trench System, Insulated Floor.

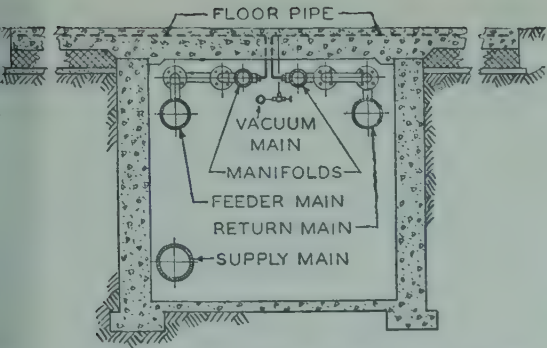

Fig. 12. Carpenter Monolithic Floor and Piping System. Center Trench System.

In many cases it is found undesirable to have pipe trenches around the outside of floors, especially in outdoor rinks, in which case the center trench system may be used to advantage. This system is suited for either indoor or outdoor rinks, as all pipe fittings are easily accessible, yet are protected at all times from the elements. Fig. 12 shows an example, with special piping connections, consisting of a ½-in. pipe connecting the outlet of each floor pipe to a small header in which a vacuum may be created in order to remove the trapped air. Operation for a few minutes each day is sufficient to insure freedom from air. Continuous power is not required to start and stop the vacuum pump, driven by a 1-hp motor.

Refrigeration Equipment

For removing heat from the rink floor the **indirect system** is generally used, the circulating medium being a brine solution of salt—sodium chloride (NaCl), calcium chloride ($CaCl_2$), or some other liquid with a low freezing point. The quantity circulated per min should be sufficient to prevent a temperature rise of more than 2 to 3 F. The cost of pumping is in direct ratio to the quantity multiplied by the head; therefore, careful designing of the brine circulating system is necessary to avoid high head pressure. Since the amount of brine to be circulated should vary according to the demand, it is good practice to have more than one circulating pump. The average indoor rink should have provisions for circulating about 10 gal per min per ton, to give a 2.8 F temperature range. This amount of brine allows 1 gal per min per 10 to 20 sq ft of piping surface, depending upon the type of service.

Using the **direct expansion system** requires a low pressure liquid receiver or accumulator, a recirculating pump, and distributing headers or manifolds. In this system, by means of an expansion valve, the liquid refrigerant from the high pressure liquid receiver is reduced in pressure, and, consequently, in temperature, flowing into a low pressure liquid receiver or accumulator, from whence gas returns to the compressor. The remaining cold liquid is circulated by means of a pump through the floor piping. A mixture of gas and liquid goes back to the low pressure accumulator, the gas going on to the compressor and the liquid being recirculated.

The term **floor temperature** has little general meaning except as applied to an individual installation where the exact point as indicated is known. The best ice for general skating is moist, but not wet, at a temperature of 32 F on the surface. A very slight increase, possibly 0.1 F, means wet ice, and a slight decrease means relatively hard ice. Skates cut into the hard brittle ice by mechanically chiseling grooves so that the ice becomes rough and covered with snow. Such ice offers undue resistance to the movement of the skate. For these reasons it is necessary that the brine or refrigerant in the rink piping also be held within close limits.

The **heat loss** from the surface of the floor is affected by air temperature, humidity, air circulation, radiant heat from sun and artificial lights, in addition to the latent heat of freezing of the water. There is frequently an additional load imposed when the temperature of the floor is allowed to rise unduly. The heat load imposed on the ice by skaters arises from warm air being fanned downward by their movement. Motionless air, however, will transmit no appreciable heat, and a layer of perfectly still dry air on an ice floor is a good insulation. Moisture in the air, however, will condense on the floor. Many ice rinks do not operate the refrigerating machinery during the night, in which case windows and doors should be closed, and activity which might cause disturbance of the air blanket on the rink floor prohibited.

Of all refrigerating installations, none has greater need for thermometers than an ice floor. Yet few rinks utilize them properly. Requirements and change of load should be anticipated, but while the ordinary refrigerating installation may call for changes of temperature of a single degree in an hour or so, an ice rink floor control should be considered in tenths of a degree in minutes or fractions of an hour. A recording thermometer which has a time lag and uncertain reading of 0.5 F is of no use here. The electrical resistance temperature indicator is suitable with central stations to which all points are connected, requiring indication of a change of temperature within 0.1 F instantly. Frequent readings show up any tendency toward floor temperature changes, which the operator may counteract at once. One of the best and quickest means of controlling the condition of ice surface is to change the temperature of the air over the ice.

Installation of an **electric resistance system** with at least 12 points is recommended to provide:

4 floor temperatures located in the ice sheet
2 brine temperatures
2 water "
2 arena air "
1 outdoor air "
1 engine-room air "

The three-wire system of electrical connections has proved suitable for ice rink installations, as it does away with all compensators or resistance correction coils, saving attention and time in installation and maintenance.

There is a wide divergence of opinion among engineers, judging from their installations, as to the amount of **refrigerating effect** necessary in enclosed rinks. Actual rink installations of practically the same size and refrigerating requirements vary as much as 100 percent in the sq ft of floor surface per ton of refrigeration. Rinks for skating clubs used exclusively for figure skating require the least refrigeration for a given area. For public skating only about 25 or 30 percent more is needed. But for arenas, with an unpredictable load demand, the necessity of starting with a floor temperature around 70 F, and for producing a skating surface within 10 or 12 hr requires a large available refrigerating capacity. Under heavy load it may be necessary to circulate the maximum amount of brine at a low temperature of 8 to 12 F.

The refrigerating load in all rinks varies at times by as much as a ratio of 3 to 1. Compressor capacity should be divided into two units at least. Under normal conditions one compressor should handle the load even with a maximum number of skaters on the ice, providing the load has been anticipated and the brine and floor temperatures prepared accordingly. The second compressor, therefore, is for emergency load purposes as well as the protection afforded by an extra unit.

For rinks with permanent ice, the refrigeration capacity should be about 0.5 tons per 100 sq ft of floor surface, and, for arenas where the ice floor is likely to be changed from day to day, it should be about 0.85 tons per 100 sq ft. Local conditions in each installation may modify the allowance. A substantial number of rinks, which were designed for winter use, have for several years been operating successfully during the summer months by running the refrigerating equipment continuously and, when necessary, at full capacity. The formation of fog over the ice in warm weather may be prevented to a large extent by circulating air over the surface, which, of course, increases the load.

There should be two or more **brine circulating pumps,** each having a capacity to take care of the ordinary normal load. This allows one pump in reserve, available for circulating a large volume of brine whenever necessary. In designing the pumps the maximum head pressure in gal per min should be set for the pumps operating together, the hp of the motor being based on the resulting head pressure and capacity with only one pump running, assuming that centrifugal enclosed impeller type pumps are used. The amount of brine to be circulated in order to keep the range of brine temperature not over 2.0 F with maximum load is 1 gal per min per 10 to 20 sq ft of floor surface in rinks where the air temperature is not over 65 F.

The brine tank has often been considered as a fly wheel from which energy, in the

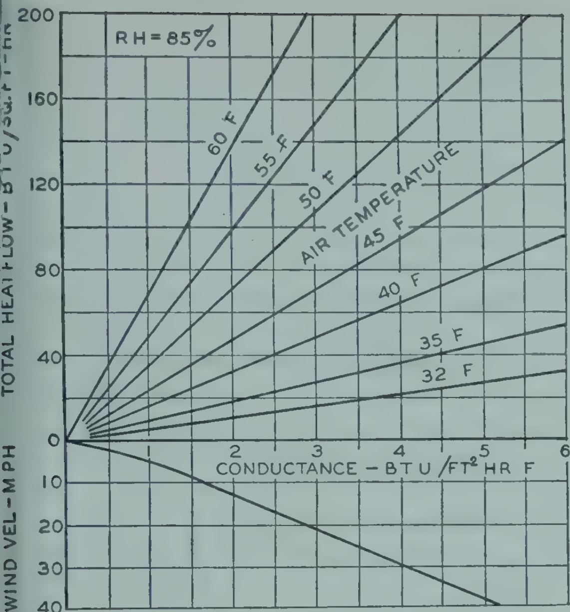

Fig. 13. Heat Transfer from Air to Ice Surface as Affected by Air Velocity and Temperature.

shape of refrigeration, could be secured in an emergency, and large capacity tanks have frequently been installed. Practice has demonstrated this to be undesirable. Better results may be secured by increasing the refrigerating capacity of the equipment.

When the **removal of ice** from the floor is to be done quickly, it is generally accomplished by warming the brine in the whole circulating system, after bypassing the brine tank and brine cooler. The brine should be heated gradually from its ice floor temperature of about 20 F by continuous circulation through the floor piping, up to about 40 F at which point the bond between the ice and floor is released, so that ice may be broken up and shoved into a suitable pit. The brine heater should be an instantaneous type with the brine circulating through the tubes. A heater containing about 200 sq ft of heating surface in the tubes, 6-in. brine connections, 4-in. steam supply at 5 lb per sq in. pressure or less, and 1½ to 2-in. condensation outlet, will handle almost any floor.

In building an ice sheet the floor is first cooled down to the freezing point, and then sprayed with a coat of water, a process repeated until the ice is about ¾ in. thick. A special nozzle to produce a fine flat spray is best, in order to prevent wrinkles or ridges and to secure even layers of water. Uniform thickness of ice should be carefully maintained. If the floor is cooled down to a low point in order to hasten freezing, it should be allowed to warm up to 32 F before being used.

The ice sheet should be **resurfaced,** usually after each skating session. An ice plane or shaver is used to shave the surface, to remove skate marks and to prevent the thickness of the ice from increasing with the spraying and moisture condensation. The process of resurfacing consists of shaving a thin layer from the surface, removing the ice chips and snow, washing the ice by pushing a substantial amount of water across it by means of squeegees. Then a light coat of water is sprayed on. The whole procedure should not take more than one hour on a large rink, with four men doing the work.

The floor piping and construction for outdoor rinks are practically the same as for indoor rinks. The design of the pipe trenches may require some ingenuity to provide proper covers. With the center trench design, as shown in Fig. 12, all pipe connections and mains are out of the way in a pipe tunnel under the floor, and there are no complications around the outside edges of the floor. The refrigerating load on open air rinks is more varied than on enclosed rinks and at times much greater, depending on atmospheric conditions. The temperature of the ice surface cannot be controlled when the outdoor temperature is below freezing; therefore the ice is frequently very hard and readily chipped. Sun, winds and rain often add greatly to the load. On the other hand, open air rinks, in addition to their outdoor atmosphere, offer many advantages, especially in the matter of low initial cost and cost of operation.

Miscellaneous Data

Soft coal cinders, used as a fill under a rink floor, frequently cause serious trouble due to a tendency to expand when wet. If confined at the rink edges, cinders may lift the floor to a point which may prevent the use of the ice. Cinders, moreover, contain considerable amounts of sulfur which,

in the presence of moisture, gives off sulfur dioxide gas, eventually destroying the pipes. The ground under a rink floor should be practically free of water; otherwise it is likely to "heave." No wood should ever be allowed to come in contact with floor piping, as it may rot and release tannic acid, which corrodes pipes.

Any brine leak, no matter how minute in a pipe buried in a concrete floor will eventually cause trouble, first by saturating the concrete to retard freezing of the water, and, secondly, by starting corrosion on the exterior of the pipe. This may eventually rupture the concrete, or necessitate replacement of the pipe, which means a complete shutdown.

All pipe joints buried in concrete should be welded, as screwed fittings of any type are a hazard. All pipe to be imbedded in a floor should be prepared to insure a perfect bond to the concrete and the concrete mixture, and the method of depositing must also conform to this necessity.

In laying a one-piece monolithic floor, it is essential that the depositing of concrete, once started, shall be continuous until completed, and in case the floor finish is of cement or terrazzo, the topping should be laid immediately after the concrete is deposited, in order to secure a perfect bond.

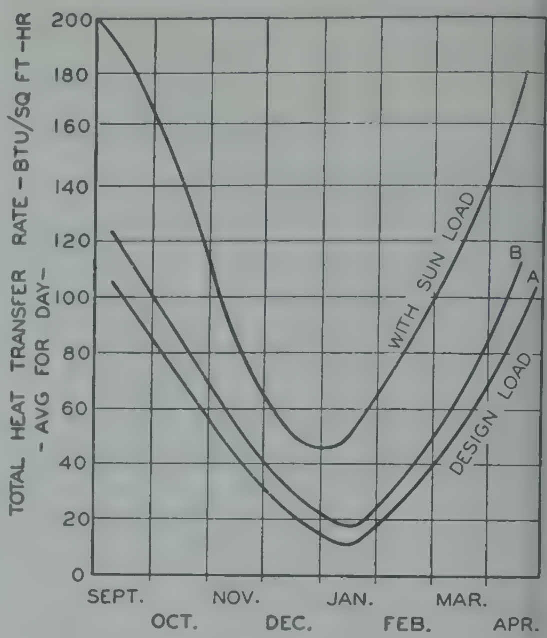

Fig. 15[1]. Maximum Noontime Load on Outdoor Skating Surface on a Clear Day—Sum of Ground, Air and Sun Loads. Lower Curve is Recommended Design Value Counting Upon Storage Effect of Ice and Equipment When Machine is Run Steadily. A is for Cloudy Day and B for Sunny Day.

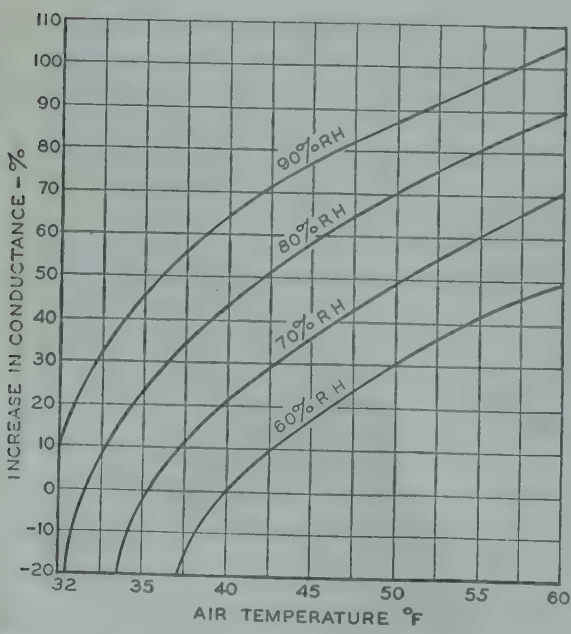

Fig. 14. Effect of Air Humidity on Heat Transfer from Air to Ice Surface.

Terrazzo top on a monolithic one-piece floor meets every demand which any cement finish can offer and has, in addition, a smooth polished surface most suitable for roller skating or dancing. It is easily cleaned, water can be removed and the floor quickly dried with rubber squeegees. The color and fine finish of terrazzo does away with the pavement-like appearance.

Water for spraying on the ice for heated enclosed rinks may be comparatively cold (water discharged from the condenser is ideal); but for open air rinks there must be heated water available at 180 F to prevent shell ice during the extreme cold weather. In order to produce a fine spray, the water should be under heavy pressure on the spray nozzle, and the spray should fall on the ice like rain in order to avoid rolls or ridges.

In order to lessen the effect of radiated heat, such as sunlight on the ice, a dark surface under the ice which absorbs heat should be avoided, or the ice may be painted with a white coat of water-soluble

casein paint, applied on top of the first $\frac{3}{8}$-in. sheet of ice. The white surface reflects the heat rays from the ice. Radiated heat rays pass through clear ice without effect unless there is some substance in or about the ice to absorb them.

The latent heat load (144 Btu per lb of water) required to freeze ice on 100 sq ft of floor surface is expressed in **Table 1** (weight of 1 cu ft of ice equals 57.50 lb).

Table 1. Latent Heat Load Required to Freeze Ice on 100 sq ft of Floor Surface

Thickness in.	Wt lb per sq ft	Total wt lb	Total Btu	Ton-hr
$\frac{1}{32}$	0.1497	14.97	2,156	.179
$\frac{1}{16}$	0.2994	29.94	4,312	.359
$\frac{1}{8}$	0.5989	59.89	8,625	.718
$\frac{1}{4}$	1.1979	119.79	17,250	1.437
$\frac{3}{8}$	1.7968	179.68	25,874	2.156
$\frac{1}{2}$	2.3958	239.58	34,499	2.874
$\frac{3}{4}$	3.5937	359.37	51,749	4.312
1	4.7916	479.16	68,999	5.749

In addition to latent heat, it is necessary to include the load required to reduce the temperature of the water to 32 F. The heat load acquired by convection from the air over the skating surface must also be taken into consideration. This depends on the temperature of the air and is affected, especially on outdoor rinks, by the velocity of the wind as summarized theoretically in **Fig. 13.**[1]

The humidity of the air, the effect of which is shown in **Fig. 14,**[1] must also be considered in heat transfer. This together with the condensation of moisture in air, may amount to a considerable load.

In addition to heat loads from rink floors, mentioned above, open air rinks frequently have an additional load due to radiated heat from the sun, which varies with the season as well as with time of day, depending on the angle of the sun. **Fig. 15**[1] gives interesting data on this subject.

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If you searched this chapter for something which was not found in it, please let the editors know.

53. DRY ICE MANUFACTURE

DRY ice is the solidified or frozen form of the well-known gas, carbon dioxide (CO_2). It is a white, semi-translucent solid, very much colder than water ice, and for rough calculation is considered to have twice the refrigerating value (at 32 F) of water ice, by weight, and four times its refrigerating value by volume.

It was first produced experimentally by Thilorier[1] about 1835. It was used commercially in the early 1890's when Elworthy[2] patented methods of manufacture and described its use. He also suggested it as a means of transporting carbon dioxide gas. In 1907 Newth[3] mentioned that in England "carbonic acid snow," as this substance is sometimes termed, was an article of commerce. In 1922 Reich[4] produced dry ice on a semi-commercial scale in California and proposed it as a cooling agent for refrigerator cars. Josephson used dry ice in 1924 in shipments of fish by refrigerator cars in Canada, and by 1925 it was sold in commercial quantities.[5] The dry ice industry has since grown with considerable rapidity, in spite of certain handicaps, until now its sales amount to about 350,000 tons annually and show evidence of increasing rapidly.

JAMES WELLFORD MARTIN, Author Chapter 53. Born 12/1/91 in Richmond, Virginia. Educated at the University of Virginia, 1911. Formerly, Chemist, Foreman of Acid Plant, Nitro Glycerine Line and TNT Plant; Assistant Chief Chemist at Carney's Point Powder Plant, Supervisor of Raw Cotton Purification Plant, Du Pont Company. Assistant Supt. of TNT Plant; Supt. of Nitric Acid Plant and Supt. of Phenol Plant, Tennessee Copper Company. From 1917 with the U.S. Army as Captain; Liaison Officer with British; later with French in Manufacture of Chemicals and Explosives; member of Inter-Allied Mission to inspect enemy chemical plants; Chief of Chemical and Raw Materials Branch of a Division in Ordnance Dept.

Research Engineer on carbon, acetylene and natural gas products, for the Union Carbide and Carbon Corp.

Head of Industrial Engineering Dept., Aliquippa Works, Jones and Laughlin Steel Co.

Chief Engineer; in charge of Production and Sales Depts., Dry Ice Corp.

Consulting Engineer (1929–42) on the design and construction of chemical plants; sales engineering for dry ice refrigeration and engineer on food handling and transportation.

Engineering Manager of Construction at Pine Bluff Arsenal, Arkansas (a 60 million dollar chemical plant); in charge of design and erection of chemical and mechanical processes, with Sanderson and Porter, Engineers and Contractors.

Author Chapter 48, 1946 Applications Volume, ASRE Data Books.

Member of Amer. Inst. Chemical Engineers; Amer. Soc. of Refrigerating Engineers; Fellow, Amer. Inst. of Chemists. Licensed Professional Engineer in State of New York and State of Florida.

At present, Consulting Engineer, New York City.

Physical Characteristics

Density, commercial dry ice, lb per cu ft	90–95
Temperature (when surrounded by its own gas), °F	−109.3
Temperature in 50 percent CO_2, °F	−123
Temperature when surrounded by air, °F	−220
Triple point, °F	− 69.9
Triple point, lb per sq in. abs	75.0
Heat of sublimation (solid to gas) at −109.3 F, Btu per lb	246.3
Sensible heat, −109.3 to 32 F	28
Total heat absorbed at 32 F, Btu per lb	274

The solid and its resulting gas are relatively non-corrosive to metals and organic materials. The toxicity of the CO_2 gas evolved during its sublimation is indicated in **Table 1.** For pressure-temperature relations see **Fig. 1.**

Principal Sources of Gas

Several sources of carbon dioxide may be mentioned as follows:

1. Gas is obtained from **wells** in New Mexico, Utah, California and Mexico. The CO_2 gas is separated from petroleum gases, compressed and converted into dry ice. The initial well pressure is often a factor in saving on compression costs.

2. The gas also occurs in **springs** and **shallow wells,** as in California and the

Table 1. Toxic Effects of CO_2 Gas[6]

CO_2 in air, %	Effect on Man
0.04 (pure country air)	None
0.08 (properly ventilated room)	None
0.8 (poorly ventilated room)	Slight
3.5	Deep breathing
6.0	Panting
10	Severe shortness of breath
15	Partial unconsciousness
25	Asphyxiation

Pacific Northwest, the location usually being associated with ancient lava flows. The gas is usually quite pure, needing only to be compressed and converted without any scrubbing process.

3. CO_2 gas is given off during the **fermentation,** for example, of molasses or grain in the production of alcohol. It is purified from odors (see **Fig. 2,** diagram of Reich Process), compressed and converted to dry ice. The conversion of dextrose and other hexoses to ethyl alcohol can be expressed simply by the chemical reaction:

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$$

The recovery of CO_2 amounts to about 5 lb per gal of alcohol produced.

4. CO_2 is a **byproduct** of certain chemical industries. In the soda industry, for example, brines (natural or manufactured) containing sodium carbonate are treated with CO_2 gas (40 percent) obtained by calcining limestone. This precipitates the sodium content as sodium bicarbonate which when heated gives off pure CO_2.

$$2NaHCO_3 = Na_2CO_3 + H_2O + CO_2$$

This again is pure gas, needing only to be compressed and converted to dry ice. The yields of CO_2 amount to about 50 percent of the limestone calcined.

5. **Flue gas** of oil, coal, gas, or coke fired boilers is also a source of CO_2. Flue gas must be scrubbed with a solution of sodium carbonate partly converted to sodium bicarbonate, which gives up a portion of its carbon dioxide when heated. The solution is recycled until it becomes fouled with sulfur compounds absorbed from the flue gas. (See diagram of absorption system, **Fig. 3.**) This absorption and release of CO_2 gas is also accomplished very economically by means of a solution of monoethanol-amine. The CO_2 is purified, compressed, and converted into dry ice. The recovery is generally about 1 lb of CO_2 per lb of coke burned.

6. **Oil refineries** and ammonia plants are as yet only potential sources. In the production of hydrogen for use in hydrogenation of certain petroleum compounds, and for use in making ammonia, the process employed is to heat some waste petroleum gas with steam at about 1600 F in tubes containing a catalyst. The reaction is represented as follows:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

The gases are conducted into another catalyst reactor where at 850 F this reaction occurs:

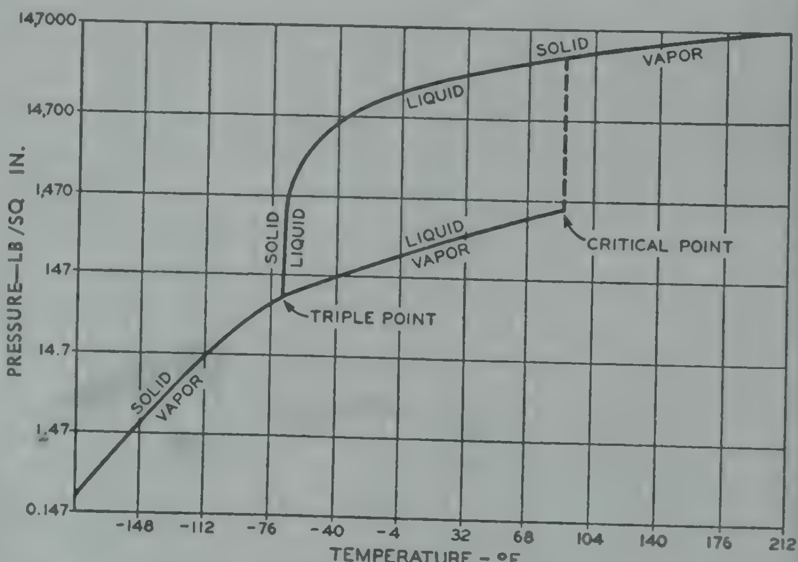

Fig. 1. Boundary Conditions—Properties of Liquid, Gaseous and Solid Carbon Dioxide.

$$CO + H_2O \rightarrow CO_2 + H_2$$

The gases have the composition of roughly 78 percent H_2, 20 percent CO_2

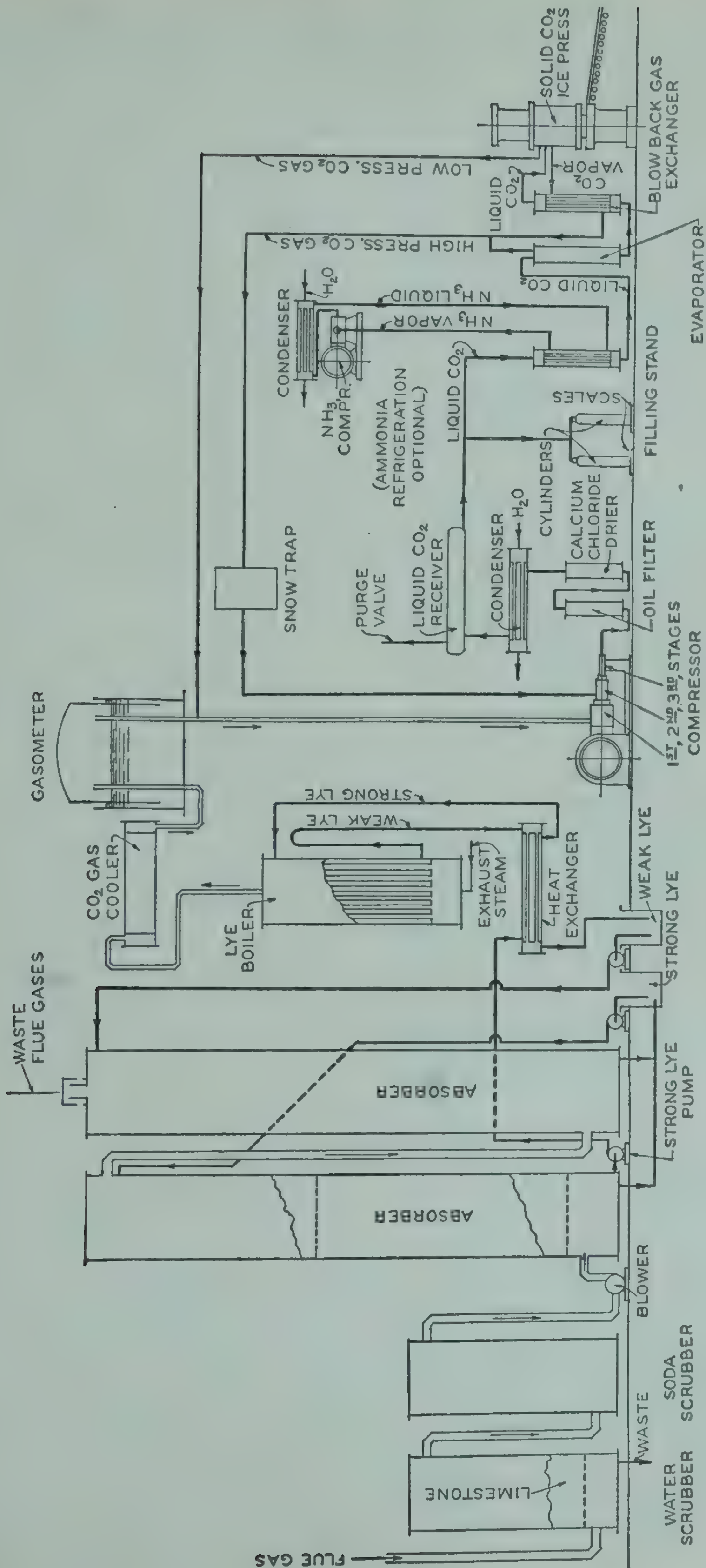

Fig. 2. Flow Sheet—Standard Carbon Dioxide Plant (Absorption System).

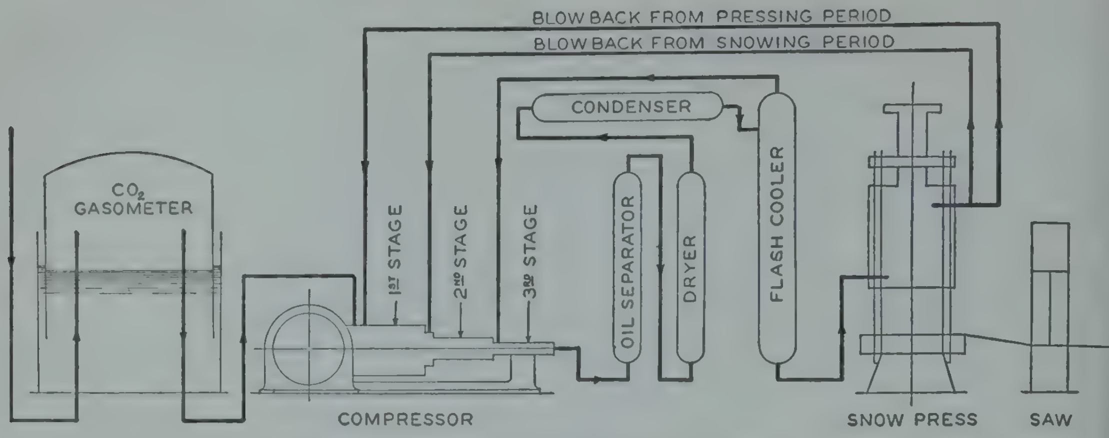

Fig. 3. Flow Sheet—Standard Dry Ice Plant.

and 2 percent unconverted hydrocarbons. This gas is now compressed and passed through water filled absorbers which retain the carbon dioxide and permit the hydrogen and impurities to proceed. The CO_2 is released from the water in a second tower known as a stripper and is obtained in pure form.

7. In **blast furnace** operation the exit gases containing CO, CO_2, H_2 and some water, may be burned for heat or used in internal combustion engines. The final products are 20 to 30 percent CO_2 and 70 to 80 percent nitrogen. From this mixture CO_2 can readily be separated by absorbing in water. The amount given off is about 7,000 lb of CO_2 per ton of pig iron produced.

The total **production of dry ice** in the United States is divided among the various sources in approximately the following proportions:

	Percent
Gas wells	5
Fermentation	35
Chemical industry (as byproduct)	45
Flue gas	15
All	100

An analysis of the **cost** of larger existing dry ice plants indicates the following approximate breakdown:

	Percent
Power (or fuel)	40
Depreciation, taxes, etc.	30
Labor (direct and indirect)	18
Materials and supplies	12
All	100

This analysis shows the importance of power in determining cost of dry ice. A plant location adjacent to a source of cheap power, either incremental or off-peak, would be ideal.

Manufacturing Process

Carbon dioxide gas is generally compressed in a three-stage compressor. The first stage takes the gas from atmospheric pressure to about 70 lb per sq in., the second to 300, and the third up to 900 or higher. The gas is cooled between each compression and after the final compression is cooled until liquefied.

Present methods of producing dry ice vary materially only in the **methods of cooling** the liquid carbon dioxide prior to solidification. The choice of method is often governed by the availability and temperature of water, the size of plant, and the cost of power. In some plants the CO_2 from the compressors is condensed by means of ammonia refrigeration, a process which materially reduces the maximum pressures involved in the system. In other plants all of the cooling is accomplished by the evaporation of increments of the liquid CO_2 as it passes through the system to the snow press. In practically all methods of dry ice production, however, the snow is produced in the press chamber by evaporation of a portion of the liquid CO_2, and this gas, usually at about 60 lb per sq in., is returned to the second stage of the compressor. Yields of snow are influenced by temperature of the liquid CO_2 and its freedom from gaseous admixtures.

In one commonly used process for the

conversion of the liquid CO_2 to solid, the liquid is cooled and expanded through an aperture in the chamber of the snow press to form carbon dioxide snow. This snow is saturated with liquid CO_2 by permitting the pressure in the chamber to rise above the triple point. The pressure is then released, leaving the snow in a dense mass. This dense, saturated snow is then pressed in the chamber by the descending upper platen of the press to form a block of dry ice.

A general flow sheet is shown in Fig. 3, a diagram of the dry ice plant in **Fig. 4,** and the time-pressure relations of the press operations in **Fig. 5.**

Dry ice as produced is generally wrapped in heavy kraft paper and placed in plant storage or insulated transportation equipment. Losses in handling between press and storage are variable but usually are about 5 percent.

Storage and Transportation

Because of the extremely low temperature of the solid, CO_2 does not lend itself readily to long-time storage. Two theoretically possible methods of slowing down the meltage are (1) mechanical refrigeration of the storage room, or (2) pressure applied to the storage space. Since neither is satisfactory because of the costs involved, the ice must serve as its own refrigerant.

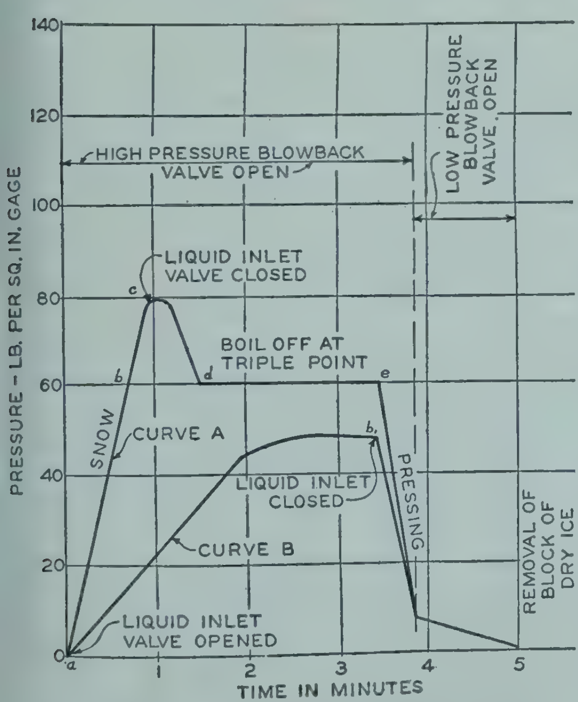

Fig. 4. Dry Ice Snow Press Operation—Curve A for Triple Point Ice; Curve B for Snow Ice.

Attempts have been made to store the dry ice for several months in large, insulated, gas tight silos. Dry ice made in winter and spring is stored in these silos for the summer peak, and the CO_2 gas liberated by the melting ice is returned to the compressors for reliquefaction and reconversion into ice. This method has not proved advantageous because (1) it is difficult for men to work in the gas in the silos, (2) the ice changes in crystal structure and becomes sugary, and (3) the capital expense and the labor costs involved are excessive. Storage for one month or six weeks has been successful where the ice is of proper crystal structure. These temporary storage boxes are so constructed that a man may load and unload, and yet keep his head above the CO_2 gas level. (See **Table 2.**)

The well type **storage container** is the only one commonly used today. The exterior walls and bottom are generally constructed of sheet metal and sealed against leakage of cold air. Several inches of efficient insulating materials are interposed between outer and inner walls. A light hinged lid or detachable cover forms the top of the container. A mattress is often provided to protect the top surface of the solid CO_2 stored within the box. Storage containers vary in size from 8 to 54 cubes capacity, the standard cube being 10 in.

Table 2. Dry Ice Losses per 24 hr, Percent

Shipping carton for 50 to 100 lb of dry ice, insulated with dry wood pulp	15–20
Shipping box for 200 lb of dry ice (3-in. insulation)	8.0
Shipping box for 2,000 lb of dry ice (5-in. insulation)	3.0
Shipping box for 4,800 lb of dry ice (6-in. insulation)	1.5
Insulated truck, well type body	1.2
Insulated railway car, well type cargo space	0.8
Plant storage, well type storage box	0.3

Shipping boxes generally follow the design of storage containers except that weight is kept to a minimum through the use of less insulation and lighter structural members. The capacities of shipping containers for solid CO_2 vary from 1 to 40 cubes.

There are now in use specially designed trucks and cars for transportation of solid CO_2. These are of the top opening or well type with a number of separate compartments, each with independent covers.

Dry ice, analyzed chemically, is always of a purity higher than 99 percent CO_2, but for commercial use its **quality** is judged mainly for freedom from odor and for structure. Dry ice from fermentation sources is examined primarily for the odor of beer or molasses; from combustion of fuels and from lime kilns, for odors of hydrogen sulfide or smoke; from natural wells, for odors of hydrogen sulfide and gasoline; and from all sources for an odor of oil brought about by incorrect lubrication of the compressors.

In **structure** dry ice should be neither soft nor brittle. Ice that is well made and is of satisfactory density may be sawed into thin slices 10 in. × 10 in. × ¼ in.; these slices will be sufficiently rugged that they may be handled. Densities of 85 to 95 lb per cu ft (equivalent to 50 to 55 lb per 10-in. cube) have been found most satisfactory.

Uses of Dry Ice

Dry ice has made possible the **shipment** and delivery of **frozen products** such as ice cream and other frozen foods in cartons. The relatively small block of dry ice is separated from the product to be shipped by corrugated board and both product and dry ice are enclosed by a corrugated carton whose walls are usually insulated with several layers of cardboard.

It has been in the **refrigerator car** and **refrigerated truck** that most development work has been done. In commercial practice the dry ice is often placed on shelves above the refrigerated load, or in slightly insulated bunkers. This is an inefficient method of using dry ice, but in the refrigerated truck it has the virtues of simplicity, quick refrigeration, and light weight. The more efficient means of refrigeration is by means of dry ice in a bunker, well insulated from the body of the car or truck. A secondary refrigerant or brine, cooled by the dry ice in the bunker, circulates through finned coils extending around or over the space to be refrigerated. Temperatures within the cooling coils and within the refrigerated space are controlled at will by a thermostatic valve which regulates the flow of the secondary refrigerant.

A proposed system uses a secondary refrigerant that cools and liquefies in a condenser within the dry ice bunker, and evaporates within cooling plates swung against the upper side walls of the car or truck. This system also is thermostatically controlled.

In refrigerator cars and trucks dry ice has the advantage of providing **increased refrigerator space.** The average load of perishable products shipped in water iced refrigerator cars in the United States is only about 13 tons, although the maximum permissible load is usually above 40 tons. This light loading is due to the fact that in a water iced refrigerator car, the temperature gradient increases rapidly above a point 40 in. from the floor. Therefore, the careful shipper of perishables will not load the car much above this safe height. In cars using a dry ice system, the refrigeration may be uniform as high as 70 in. from the floor. In addition, much of the space occupied by the water ice bunker (30 in. at each end of the car) is available for cargo

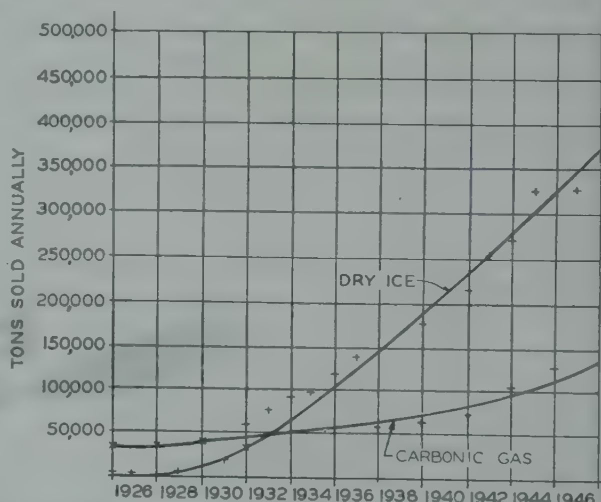

Fig. 5. Growth in Sales of Dry Ice and Carbonic Gas in the United States.

space in cars cooled from the small elevated dry ice bunker. For example, a dry ice car in shipments of pork products from Indianapolis to San Fran-

cisco will carry 88,000 lb, while the maximum with the standard water iced car is 26,000 lb. An increase of load amounting to 75 per cent is normally possible.

In cars equipped with dry ice refrigerating systems temperature distribution is better than in water iced cars. Refrigeration is distributed through coils or plates along the upper part of the side walls of the car. In this way, the average distance of lading from refrigeration is about 2 ft and there is no spot in the car that is as much as 6 ft away from its cooling surface. In the present standard refrigerator car the average distance of product from refrigeration is 10 ft, while the lading in the center of the car is 17 ft from any refrigerating surface. The temperature difference from end of car to door and from bottom to top of car is considerably less in the dry iced car.

Comparative economy. It was early found that dry ice refrigeration should be limited to precooled lading. Fruit or other products put into the cars directly, without precooling, required so great an amount of dry ice to remove field heat as to make its use impracticable. The larger portion of refrigerated shipments in this country are now precooled, however, and the practice of precooling is growing rapidly.

The experience gained in the large number of carload shipments made under all kinds of weather conditions indicate that dry ice is competitive in cost of refrigeration when its price is below $30 per ton.

One can readily see that this comparison does not correspond to the comparative cost of heat absorbed. Water ice at $4 per ton absorbs 288,000 Btu per ton, or 1.4 cents per 1,000 Btu, while dry ice at $30 per ton absorbs 540,000 Btu per ton, or 5.5 cents per 1,000 Btu. A partial explanation of the unexpectedly high efficiency of dry ice can be found in the thermostatic control and the proximity of load to cooling surface.

Other factors are involved in the operating conditions. The ordinary refrigerator car requires four to five tons of ice to fill its bunkers. When about one-third of this ice melts, it must be replenished or the temperature inside the car may rise. This lower two-thirds of the ice in the bunker constitutes the cooling surface necessary to cool the air in the car. In the dry ice car with cooling coils, only sufficient dry ice to last to destination is required. The average trip of a refrigerator car is about four days. For this trip the average amount of water ice required is four to five tons, of which three tons remain in the car to the destination. For the same trip the dry iced car requires an average of not more than 1,000 lb. The one to two tons of water ice melted cost only $4 to $8, but four or five tons of water ice may be used costing $16 to $20. One-half a ton of dry ice might cost $15.

Refrigeration of frozen foods. Dry ice has proved to be of exceptional value to the shipper of frozen foods. To limit the growth of micro-organisms and retard the activity of enzymes in most frozen foods, nonfluctuating temperatures below 15 F are desirable during storage and transportation.

It is practically impossible, except in cold weather, to maintain such temperatures throughout shipping loads by the use of water ice and salt. Mechanical refrigeration on trucks or railroad cars has not proved entirely satisfactory. Dry ice, on the other hand, has demonstrated conclusively its ability to maintain in car or truck a uniform, non-fluctuating temperature of below 10 F for more than a week at a time. The use of dry ice for refrigerating frozen foods is feasible from a cost standpoint, even at prices above $30 per ton.

Much dry ice is used now in liquefiers or **pressure vessels** in which solid carbon dioxide melts to liquid carbon dioxide. These vessels are usually cylindrical in shape and designed to withstand the pressure of liquid carbon dioxide at normal temperatures. The dry ice is placed in the vessel; there it absorbs heat and becomes a liquid suitable for any of the uses to which liquid CO_2 is fitted. Such liquefiers are often used as tanks from which to fill the customary steel carbon dioxide cylinders of commerce, or as a source of carbon dioxide in soft drink bottling establishments. The advantage of shipping carbon dioxide in the solid form instead of a heavy steel cylinder necessitated by the liquid form is obvious.

One of the major uses of dry ice in the **mechanical field** is for the purpose of preserving the temper of aluminum rivets in the airplane industry. Its use for cooling, one of the elements in a shrink fit, in machine shops is also very general. A large war use of dry ice has developed in the testing of instruments that must function in low temperature surroundings such as aviation instruments for high altitude flights.

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If you searched this chapter for something which was not found in it, please let the editors know.

54. REFRIGERATION IN ENGINEERING CONSTRUCTION

USE of mechanical refrigeration in exclusively civil engineering construction is in three distinct fields: (1) Rapid **cooling of concrete** in mass structures during construction, so that temperature changes will not cause excessive cracking; (2) **solidification of foundation** materials by freezing to control water or partially-fluid soil during the construction period; (3) **air conditioning** of structures to control corrosion and growth of organisms. In addition, cakes of ice are occasionally used to **lower heavy structures,** thus permitting removal of jacks or other supports, and sometimes refrigerants are used to **shrink metal** when fitting up members.

HAL W. HUNT, Author Chapter 54. Educated at University of Iowa, CE, 1926. Designing and constructing highways and bridges from 1926–31; Construction Engineer on locks, bridges, and dams for various contractors and Tennessee Valley Authority, 1931–39; Associate Editor, *Engineering News Record,* 1940–47; Executive Engineer, Western Foundation Corp., 1947 to date.

Author of numerous articles on foundations and heavy construction; Chapter 49, 1946 Applications Volume, ASRE Data Books.

At present, Executive Engineer, Western Foundation Corporation, New York, N.Y.

Cooling Masses of Concrete

Cooling of concrete for mass structures, one of the largest fields for refrigeration in heavy construction, is relatively new, having been developed in the past 20 years to keep pace with rapid placing of concrete in structures ever increasing in size. The purpose is to minimize the temperature rise from heat of hydration of cement immediately after placing and to speed the inevitable shrinkage so that the structure quickly reaches a constant size. During the entire cooling period, the mass structure shrinks, and joints in the interior open up. Artificial cooling is used **to speed the temperature change,** first, to cause the shrinkage while the concrete is relatively plastic and, second, so that the joints will reach their maximum opening and then can be grouted

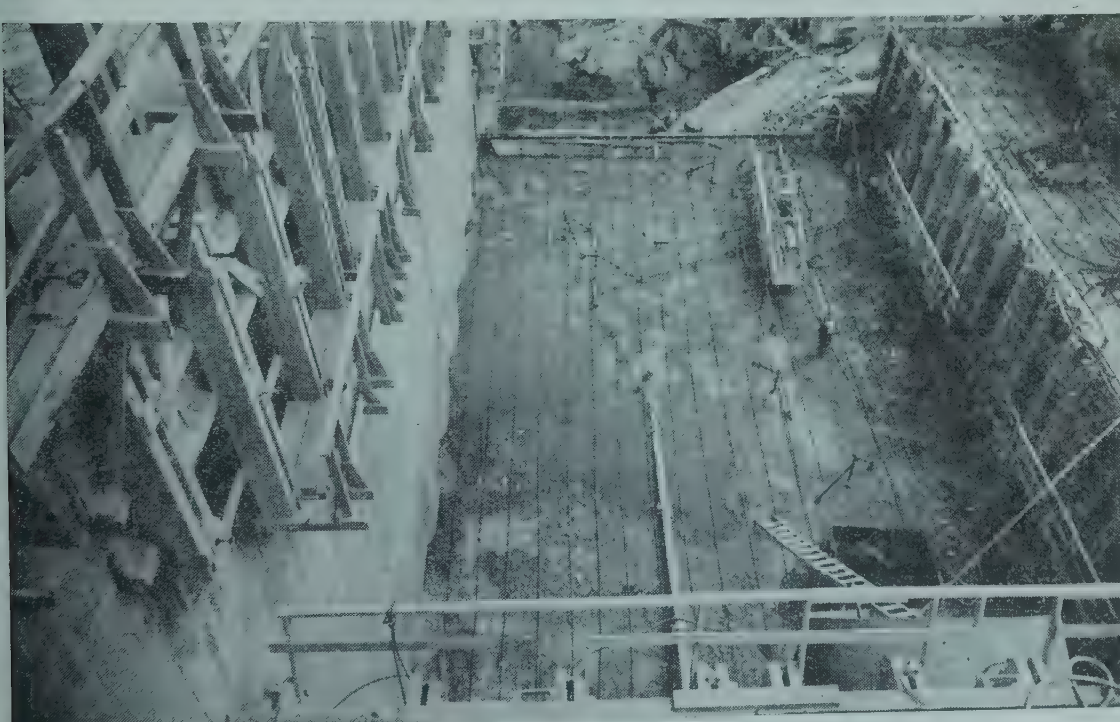

Fig. 1. By Keeping the Temperature of the Concrete at Fontana Dam Low with Refrigerated Water, Lifts of Concrete Could be Added without Delay.

Fig. 2. To Prevent Temperature Changes that Might Loosen the Concrete on the Foundation Rock, Cold Water Was Circulated through Tubing During Construction of Norfork Dam.

full before stress from the load in the reservoir comes on the structure. Thus, the full mass of the structure takes compression without internal movement.

It is becoming increasingly certain that cooling of concrete in the fall, to hold the temperature low, is very effective in controlling surface cracking. Without refrigeration, sudden drops in temperature during September and October may produce marked temperature gradients at and near the surface of the concrete, such that the ultimate tensile strength of the uncured concrete is exceeded. Millions of incipient cracks are created, many of which later open and cause surface deterioration.

Nearly all large concrete dams built in recent years have been artificially cooled. Some have depended on circulated water from the stream, but this has definite limitations that often uneconomically delay the concreting schedule. It also appears that no refrigeration system installed to date has been adequate to provide the cooling desired. Hence, the equipment described as installed in the several projects mentioned below should not be taken as a criterion of what is economically desirable. For example, at Fontana Dam, exactly double the installed machines were needed, but could not be obtained due to wartime restrictions.

Artificial cooling may be used to reduce the temperature of the components of the concrete before placing, or refrigerants may be circulated through pipes in the concrete in the structure, or both methods may be used.

At **Norfork Dam** in north Arkansas,[1] built by the Corps of Engineers of the Army, both schemes were used (**Figs. 2 and 3**). In hot weather it was necessary to cool the aggregate and mixing water to a maximum temperature of 75 F at time of placing, although the preferred maximum temperature was 67 F. Cooling was accomplished by adding 75 lb of ice per cu yd of concrete to the coarse aggregate. The ice was delivered in 300-lb blocks, crushed and weighed at point of use, then spread evenly over the aggregate as it was carried into the mixer on a conveyor belt. The mixing water was cooled by a refrigerating machine set up at the plant.

Concrete in mass dams ordinarily is placed in lifts of not more than 5 ft, and limitation is placed on the time that must elapse before placing successive lifts or adjacent blocks. The elapsed time requirement can be reduced by artificial cooling, and this was done at Norfork Dam.

On the foundation rock, 1-in. O.D. tubing was spaced on $2\frac{1}{2}$-ft centers following the rock contours as closely as possible, with the coils at no place more than 15 in. above the rock. Above the foundation the coils were placed on top of each concrete lift with horizontal spacing of 5 ft. The

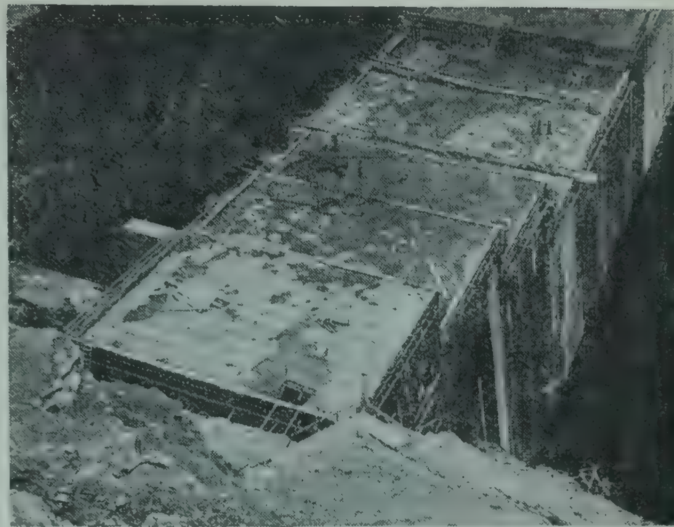

Fig. 3. Tubing for Cooling Water on Norfork Dam.

coils were contained entirely within the limits of a single monolith. Water, at a temperature not exceeding 50 F, was pumped through the tubing at a rate of 3 to $4\frac{1}{2}$ gal per min. In summer the cooling water was reduced to the required temperature by refrigerating plants, but in winter it was possible to use river water.

Electrical resistance thermometers were installed in the concrete, with wire leads extending to an inspection gallery. Cooling continued until the desired temperature was obtained. The cooling period in the summer ranged from 50 to 65 days for the first lift on foundation rock to about 35 days in smaller blocks of concrete near the top.

At **Denison Dam** in Oklahoma and Texas, also built by the Corps of Engineers for flood control and power, refrigeration was used to cool the concrete around the power unit. The concrete was poured in shallow lifts and cooling was used to assure that the bond of the concrete to the steel liners would not be broken by subsequent shrinkage.

At the 2,800,000-cu yd **Fontana Dam**,[2] completed in 1945 by the Tennessee Valley Authority on the Little Tennessee River, both river water and refrigerated water were circulated through coils embedded in the concrete. Thin-walled 17-gage steel tubing 1 in.-O.D. was laid horizontally at 6-ft 3-in. centers on top of the typical 5-ft lifts. In zones where it was necessary to keep contraction to an absolute minimum, $2\frac{1}{2}$-ft lifts of concrete were used with a closer spacing of cooling coils. The refrigeration plant for cooling the

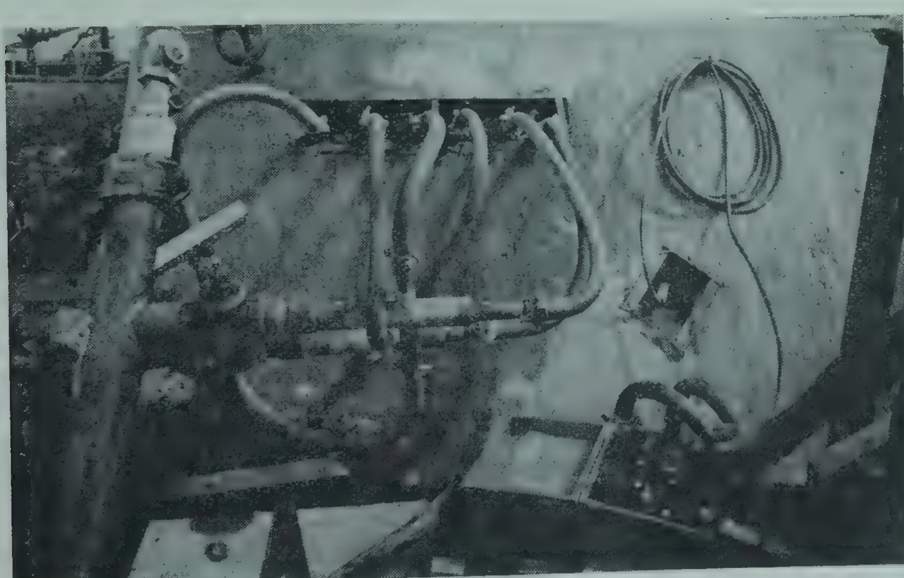

Fig. 4. Piping and Test Equipment Give Fontana Dam Appearance of Industrial Plant.

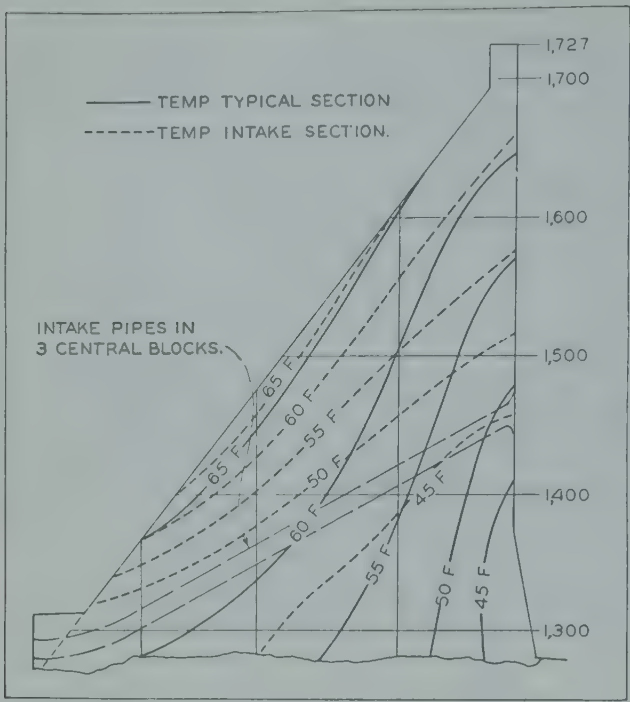

Fig. 5. Final Temperature at Fontana Dam.

water had one ammonia compressor with a capacity of 62 tons, another with a capacity of 193 tons, and one ammonia condenser with about 2,200 sq ft of effective tube surface.

At **Hiwassee Dam** of the TVA, two 9× 9-in. two-cylinder ammonia compressors, with supplementary condenser and cooling coils, were used to reduce the temperature of concrete mixing water from 80 to 40 F during the summer months.

Pioneered by Bureau of Reclamation

Bureau of Reclamation engineers first developed the theory and practice of artificial cooling of mass concrete dams. Cooling has been used experimentally on Owyhee Dam and extensively on Boulder, Grand Coulee, Shasta, Friant, and others.

Probably the largest job of concrete cooling ever undertaken was the 4,400,000-cu yd **Boulder Dam**[3] constructed in the hot and arid desert section of Arizona and Nevada. Where normal heat cements were used, cooling from as much as 130 F to less than 50° was accomplished in three to four months, but where low-heat cements were employed, maximum temperature was little more than 90°, again cooled to about 50 F. Cooling coils in the dam were 1-in. O.D. tubing spaced at 3 to 5-ft centers vertically and on 3½ to 5¾-ft centers horizontally. The coils were connected to header pipes through hose and standard fittings. Total length of all cooling pipe was 571 miles. The ammonia brine plant used at Boulder had three separate but cross-connected 275-ton capacity units to give a total refrigeration effect of 825 tons **(Fig. 8)**.

At **Friant Dam**[4] of the Central Valley Project in California, a 238-ton capacity plant cooled and circulated water through small pipes spaced at 2½ to 5-ft centers on 5-ft lifts of concrete. For cooling the concrete prior to placing, a plant for making ice crystals for chilling the mixing water had a capacity of 115 tons of ice per day. In this

Fig. 6. Pipe Loops Connect Tubing on Dam.

nachine, frost was continuously scraped rom the inner surface of a corrugated ylinder, around which ammonia circulated t 9 F. The output of the ice crystal nachine—water at 32 F—contained as nuch as 50 percent ice crystals.

The scheme of pumping river water hrough the cooling pipes was followed at Grand Coulee, but there is a record of a urtailed concrete schedule awaiting cooling to a level where additional lifts could be placed. Pumping of water at Coulee continued for five years to reduce the temperature of the center structures to 45 F.

Subsurface Use of Refrigerants

The control of unstable and water-bearing soil by freezing, during a construction period, has been in use for more than 50 years. Common practice is to put down a series of double pipes in a circle of larger diameter than the required shaft and freeze a wall of earth by circulating cold brine down the inside pipe and letting it rise through the outside pipe. With the first movement of the brine, temperatures fall very rapidly but the rate of change slows considerably as the freezing point of the material is approached. Sand freezes as hard as many kinds of rock and has a dependable compressive strength in the frozen ring. Clays are slow to freeze. Widely different applications in heavy construction practice illustrate many possibilities of this use of refrigeration.

Underpinning a Floating Building

At Sao Paulo, Brazil, a 24-story, 300-ft reinforced-concrete office building on concrete piles, just being completed, was found to have settled at one corner so it was more than 2 ft out of plumb at the top. The movement was toward an excavation for construction of an adjacent structure. Investigation showed that the new excavation had initiated movement in a lense of fine, wet sand surrounding the group of concrete piles that supported one corner of the building.

After cement grouting and an injection of aluminum salts had proved unsuccessful in solidifying the soil, the ground beneath the foundation was frozen. For this purpose 160 double-wall circulation pipes of 2- and 4-in. diameter, respectively, were put down to a depth of 60 ft into firm ground that lay beneath the lense of quicksand, which was quite close to the ground surface. After an eight months' period of circulating brine solution through the pipes, the block of ground was frozen to a temperature of −4 F. Holes of about 4 ft diameter were excavated through the basement of the building, and through the

Fig. 7. Quick Connecting Couplings Speed Work in Field.

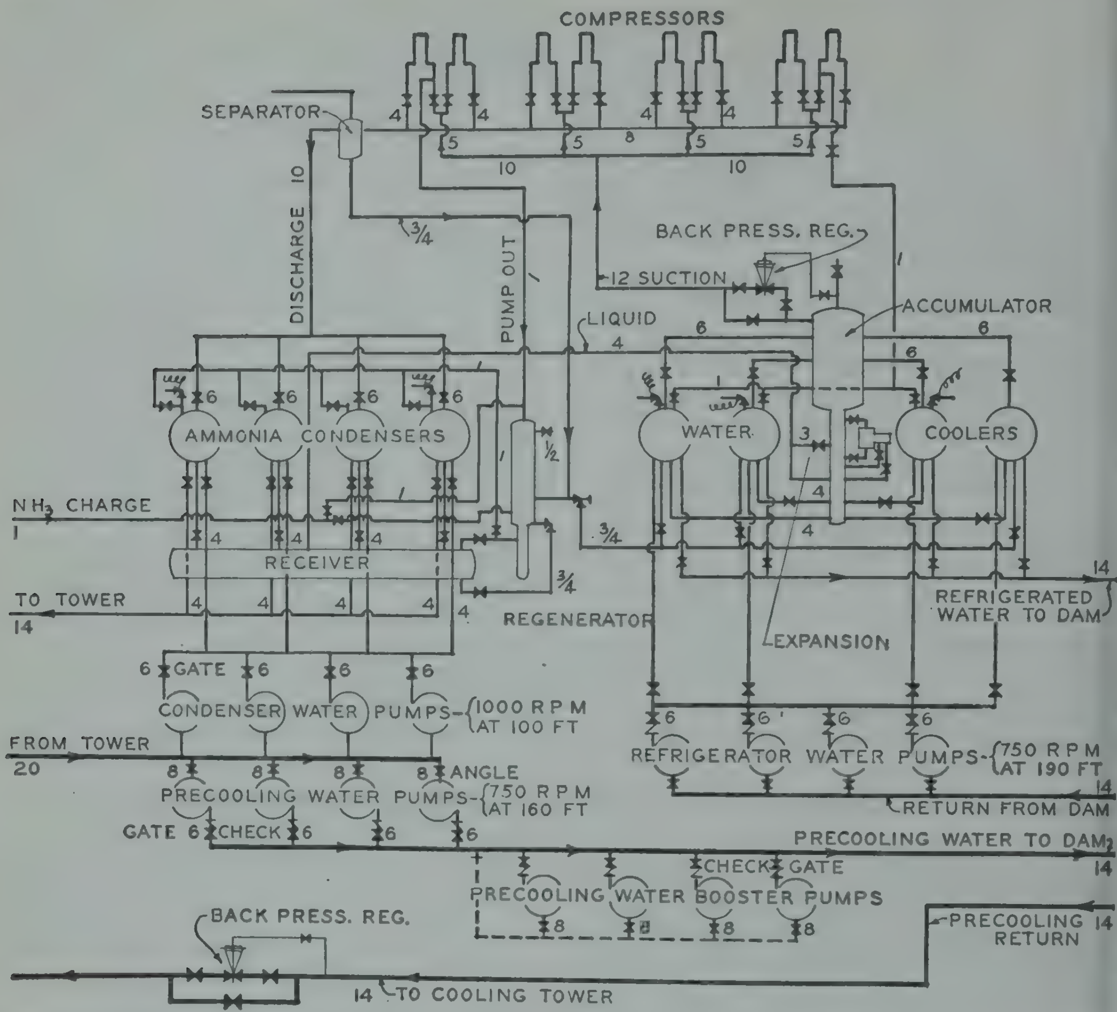

Fig. 8. Layout of Refrigerating Apparatus for Cooling Coils Embedded in Concrete of Boulder Dam.

frozen blocks into firm soil. The holes, adjacent to the columns of the building, were filled with concrete (made with an admixture of calcium chloride to accelerate setting) to form piers. These concrete columns, poured to a top elevation slightly below the existing footings, provided support for the 40 jacks, ranging in size from 100 to 950 tons each, used to tilt the building back into plumb.[5]

Soil Sampling by Freezing

Undisturbed cohesionless soil samples have been obtained by freezing the lower portion of the material to form a plug. In a pioneer application, under direction of the Corps of Engineers of the U. S. Army, freezing was accomplished by circulation of pure grain alcohol at −22 F through a chamber at the lower end of the sampler.[6]

Installation of this chamber required sinking a 10-in. casing to the top of the stratum to be tested. Inside this a 6-in. pipe was lowered to the depth at which the sample was desired. Then from the bottom of the smaller casing a 2⅞-in. diameter sampler was extended to enclose the material desired and the 6-in. pipe extended to the sample level. Next, soil was removed from between the 2⅞-in. and 6-in. pipe and the alcohol circulating device lowered so that it could freeze a plug into the bottom of the 2⅞-in. pipe. Removal and testing of the sample followed.

Exploration at Kentucky Dam

Before start of construction on **Kentucky Dam**, built by the TVA at Gilberts-

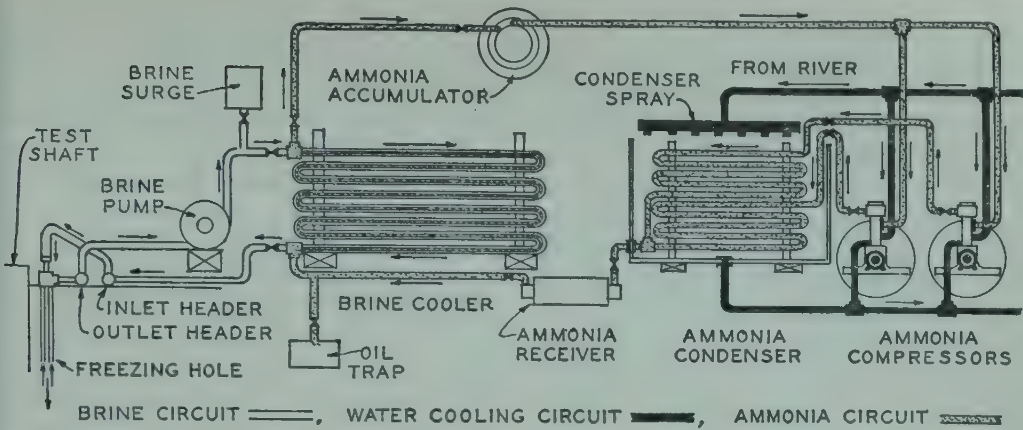

Fig. 9. Freezing Plant Used on Test-Cell at Kentucky Dam.

ille, Ky., a sheetpile test cell 90 ft deep nd 20-ft diam was driven through sand, ravel and boulders to bedrock to determine the practicability of driving a sheetile cofferdam for unwatering of the onstruction site and to uncover a large rea of bedrock for examination (Fig. 9). The area around the outside of the test haft was frozen to form an impervious heath to keep out the water.[7]

The freezing layout at the test shaft onsisted of a ring of 31 vertical pipe assemblies around the perimeter of the shaft nd 12 in. out from the sheet-piling. Individual pipe assembles in the series were at 27-in. centers and extended to bedrock. An outer casing of 3-in. pipe, open at the bottom, was driven to rock and a hole drilled on into the rock so that pipes carrying the old brine could reach into the rock and ontact and solidify the flow of groundwater in the rock itself. Inside the 3-in. casing a 1-in. tube was used to carry incoming brine to the bottom of the hole and on into the bedrock. A 2-in. pipe was slipped over and made fast at the bottom of the 1-in. pipe, thus serving as an insulating jacket to keep the warmed return brine in the annular space between the 2-in. and 3-in. pipes from coming in contact with the 1-in. cold delivery pipe.

The cooling installation consisted of two vertical duplex 9×9-in. compressors. The ammonia atmospheric condenser was made up of 10 stands of 2-in. pipe, each stand being 12 pipes high and 8 ft long. The brine cooler was a series of double pipes composed of 2-in. pipe inside 3-in. pipes, consisting of four stands, each being 14 pipes high and 16 ft long. Normal capacity of the complete installation was 46.5 tons, but unfavorable construction conditions kept the actual capacity to 28 tons. About 1,500 gal of brine was used in the brine system.

Job authorities found that a continuous outside frozen sheath did not form until water in the shaft was at 32 F or below, until temperature of ground water in observation holes at the shaft had remained well below freezing for some time, and until temperature of the ground water in test holes 5 ft outside the shaft had fallen to near freezing. For use under similar conditions, job engineers recommended larger outer casings than those used, spaced closer together and closer to the open shaft. Also, they suggest using insert pipes smaller than 1 in. and a protective casing larger than 2-in. pipe to permit incoming cold brine to travel with greater velocity and reach the bottom of the freezing pipe at a lower temperature.

Arch Dam of Frozen Earth

A flow of flour-fine glacial silt through a 120-ft wide gulch at **Grand Coulee Dam** was stopped by freezing an arch shaped beam of the saturated silt across the mouth of the channel.[8] The arch was made 20 ft thick with a 105-ft radius to provide an adequate dam to resist the thrust from a head of 40 ft of material weighing 90 lb

per cu ft, computed as having a thrust of 75 percent of full liquid pressure.

To make the dam effective in three weeks' time a spacing of 30 in. between freezing pipes was used. This spacing was determined by assuming that, with 10° brine, 6 in. of material would be frozen in two days, 12 in. in eight days and 15 in. in 20 days. Actually, freezing was effected at a somewhat greater speed.

The arch was formed by eight parallel rows of points with 16 points in a header group. Some 25 extra points were installed on each buttress haunch to increase the bonded area and lessen the tendency toward sliding. All of the 377 points used were 43 ft long, formed as shown in **Fig. 10.** The brine was forced down the 1½-in. pipe, returned in the annular space between the 1½ and 3-in. pipes, and was expelled at the tee. The 3-in. pipes were driven with a 300-lb drop hammer striking against a heavy drive-coupling.

An ammonia-brine plant consisting of three separate systems was used. There were (1) the brine system that cooled the material to be frozen; (2) the ammonia system that cooled the brine; and (3) the cooling water system that cooled the ammonia. Brine was cooled by expansion of liquid ammonia in two brine coolers. It was pumped by 7½-hp centrifugal pumps through coolers and down to the top of the arch, where it was separated to go into two 3-in. supply headers.

Cost of the plant, including installation

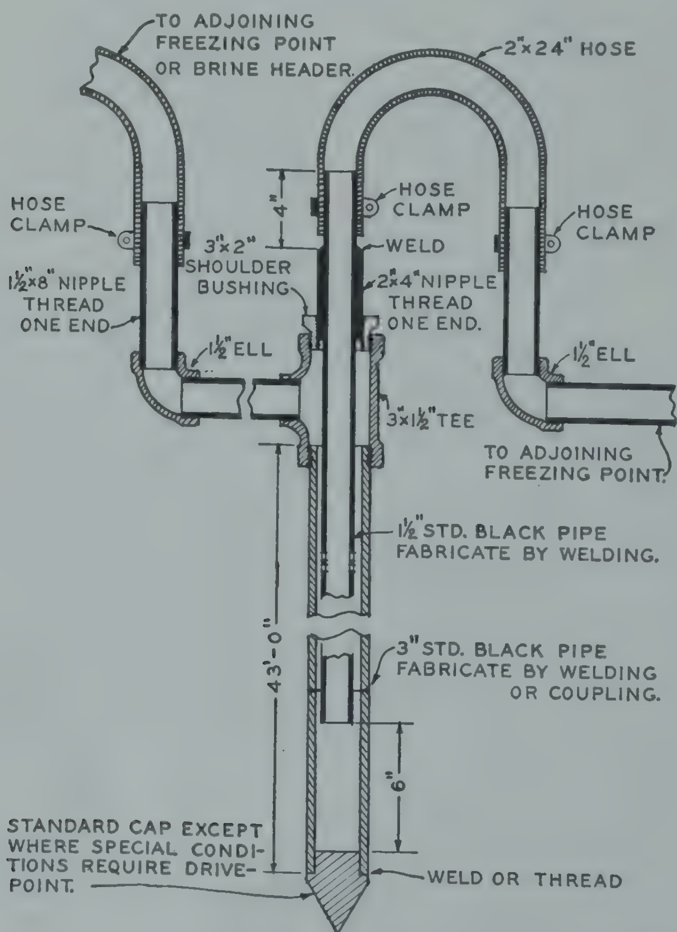

Fig. 10. Freezing Points Numbering 377 were Sunk Deep into the Slide in the Location of the Ice Dam and Cold Brine was Pumped through them to Freeze the Water Soaked Silt at Grand Coulee.

and operation for two months, was about $30,000, of which $10,000 was for labor. This total represented the cost of freezing an arch 100 ft long, 20 ft thick and 40 ft high containing about 3,000 cu yd of semi-liquid material, a unit cost of $10 per cu yd.

Shaft Sinking by Soil Freezing

Shaft sinking by freezing is a common European practice that has been used to open up mines with shafts more than 2,000 ft deep through water-bearing strata. American construction has only a few records of use of refrigeration in shaft sinking, largely because valuable mineral deposits have not been found at great depths under water-bearing soil.

Planned use of refrigerants in shaft sinking for tunneling and mining is well illustrated by construction of two ventilation shafts for a vehicular tunnel under the Scheld River at Antwerp, Belgium, about 1932.[9] The shafts were 70 ft in diameter through water-bearing strata, but freezing of a thick circumferential wall of soil made it possible to excavate to the required depth of 87 ft without interior bracing in the shaft, thus simplifying and speeding work on the structure to be built.

For freezing the cylindrical cofferdam, 116 holes were bored, one set on a circle of 86 ft diameter and the second on a circle of 78 ft diameter with a circumferential spacing of the holes of $4\frac{1}{2}$ ft. Each hole was sunk to the clay stratum about 90 ft below ground level. In each hole a steel pipe of 6-in. diameter was sunk and sealed at the bottom. Inside this outer pipe was inserted a second pipe, 2-in. in diameter and open at the bottom to form a freezing circuit through which a brine solution was passed to reduce the temperature of the ground to the freezing point. Brine was used at −4 F from a 90-ton ammonia system.

The period required for freezing the ice wall was about four months, and it was maintained in a frozen condition until concreting of the ventilation shaft had been completed. The shield for the vehicular tube was driven through the ice wall and directed through a wooden bulkhead, placed in the concrete for passing the ventilation shaft.

Deep Mine Shafts

The best example of the current deep shaft practice is found in the Campine district of North Belgium, where such great advances have been made in developing the freezing process for shafts 1,500 to 2,000 ft deep that previous applications lose their importance as examples to be studied.[10] Sinking in stages by freezing has in some shafts alternated with cementation.

Some of the most notable work was sinking of two shafts for the Helchteren and Zolder projects, where 2,034 ft of ground were frozen by a single current of refrigerating fluid in seven months' time. Sinking and lining took $21\frac{1}{2}$ months. The cost, aside from fuel and lining, was $1,177 per ft.

In the same area two shafts were sunk by freezing for the Houthaelen Coal Mine after cementation had been tried and abandoned. Both shafts were sunk to more than 2,100 ft through 1,968 ft of water-bearing ground and through a fissured stratum of sandstone about 33 ft thick overlying coal. Borings for freezing pipes were spaced at about 3.5 ft on the circumference of a 36-ft diameter circle and were continuous from the surface to a full depth of more than 2,070 ft. The borings were cased to 1,148 ft.

The freezing plant was in six units with a total capacity of 2,891 hp, each unit having a capacity equivalent to 100 tons of ice per day. Ammonia was used at a pressure of 15.4 to 26.4 lb per sq in. Chloride of calcium with point of freezing at about −16 F was used as the circulating brine. Flow of brine through each freezing pipe was 282 cu ft per hr at a velocity of 3.67 ft per sec in the descent and 0.98 ft in the riser pipe. The equivalent of 158,000 tons of ice was used for one shaft and 234,000 tons for the other.

Permanent Installations

In contrast to the temporary use of refrigerants for cooling of mass concrete and freezing of water-bearing soils, is the installation of permanent equipment for conditioning air to retard growth of organisms or to prevent corrosion. The Bureau of Reclamation has found that dehumidifying

by cooling, then warming the air to the temperature of the surrounding structure, has been effective in reducing slime accumulations in inspection galleries.

During the humid season of the year, the normal temperatures of the galleries and of mechanical and electrical equipment within the dams are appreciably below the dew point temperature of the outside air. This temperature leads to the condensation of moisture from air entering the galleries and its deposit upon the walls of the galleries and the mechanical and electrical equipment.

Moisture accelerates the growth of microscopic organisms and the formation of slime upon the walls of the galleries and causes the rapid deterioration of paint films with the consequent corrosion of metal surfaces. Moisture may also permeate the electrical insulation on wiring and equipment and cause its breakdown.

Since it is essential that a reasonable movement of air be maintained throughout the galleries, the complete solution to the problem of moisture condensation lies in the dehumidification of the ventilating air before it is introduced into the galleries.

The air is cooled by extended surface coils, with water chilled by mechanical refrigeration, to remove all moisture possible. The air then is reheated to normal gallery temperature, by heat rejected to the refrigerant condenser, and forced through the galleries by a centrifugal blower.

The same principle is applied in automatic pumping stations, particularly where there are no attendants. Corrosion and subsequent failure of electrical parts is prevented by dehumidification of the air, controlled by humidistats. Controlled freezing and thawing for testing of engineering materials and constant temperature and humidity chambers are other examples of use of refrigerants in engineered construction.

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If you searched this chapter for something which was not found in it, please let the editors know.

55. CHEMICAL INDUSTRIES AND REFRIGERANT MANUFACTURE

REFRIGERATION is an essential tool used by the chemical engineer in controlling both the speed and the direction of chemical reactions. The physical processes of freezing liquids, liquefying gases and crystallizing solids from solution, widely employed in chemical operations, also involve the removal of heat from the material under treatment.

Considerations of operating cost lead the chemical engineer to design his equipment and processes to accomplish as much of the required cooling as possible with water from deep wells or other sources having natural low temperature. Refrigeration is used only to the extent necessary to meet deficiencies of the natural cooling medium. The design problem must be solved by balancing the size of the operating units, their heat transfer surfaces and their costs against the cost of producing by artificial means the lower temperatures needed to permit smaller units to be used. Most frequently required is an increase in the rate of heat transfer out of a reaction zone attained by lowering the temperature of the cooling medium. Otherwise stated, a specified low temperature must be maintained in the zone of reaction. Thus the geographical location of the plant, which controls the temperature and volume of cooling water, is quite as important as any other factor in determining the need for refrigeration.

Elsewhere in this volume a great variety of chemical processing applications of refrigeration are discussed as essential operations in many industries. These may or may not be considered parts of the chemical industry itself, depending upon one's scheme of classification. This treatment of refrigeration applications in chemical processing leaves for discussion here only those processes peculiar to chemical manufacturing operations.

As already noted, the purposes for which refrigeration is employed in chemical processing are:

1. Control of reaction rates
2. Control of solubilities
3. Liquefaction of gases and vapors
4. Solidification of liquids.

Typical of the first group are the **nitration and diazo reactions.** The second group includes a variety of separations depending upon **crystallization of** different **salts,** different hydrates and different double salts from solutions at specific temperatures as well as concentrations of the solution. Refrigeration of **mixtures of vapors with gases** frequently supplies a convenient method of separating the constituents of such mixtures (natural and manufactured gas), and reduction of temperature lowers the pressure necessary for liquefying gases (chlorine). **Freezing of liquids** is often employed as a purifying or separating step where a dissolved constituent of a mixture possesses a higher freezing point than the principal mass (removal of stearin in refining vegetable oils and solvent refining of lubricating oils).

Production of cold in the chemical industry employs all the known methods, the

DAVID HERBERT KILLEFFER, Author Chapter 55. Born 12/22/95 in Columbia, Tennessee. Educated at University of North Carolina, BS Chem. Eng.

Formerly with Brown Laboratories, Nashville, Tenn., 1915; Chemist, Nashville, Chattanooga and St. Louis Railway, 1916–18; Chem. Engr., Calco Chemical Co., Bound Brook, N.J., 1918–20; Market Editor, Drug and Chemical Markets, New York, 1920–22; Associate Editor, *Industrial & Engineering Chemistry*, New York, 1922–28; Contributing Editor, 1931–44; Technical Dir., Dry Ice Corp. of America, New York 1928–31; Bur. of Employment of Chemists Club; New York, 1931–34; Secretary, Chemical Engrg. Equipment Inst., New York, 1933–34; Consultant, 1931 to date.

Contributing Editor, *Scientific American*, 1926–28; 1936–48; author Chapter 50, 1946 Applications Volume, ASRE Data Books, and numerous technical articles, books, etc.

Member, ACS, AIChE, AAAS, AIC, Amer. Inst. of the City of New York, the Chemists' Club, etc.

At present, Chemical Engineer, Tuckahoe, New York.

choice of one or another depending upon the individual circumstances of the process and the plant. Some operations, such as the diazo reaction in the production of dyes, can be best carried out by the addition of ice to the reacting mixture. Others utilize conventional **mechanical** or **absorption refrigerating machines,** depending on the plant's overall balance and economy between mechanical energy and heat. Finally, many processes employ the **material being processed itself** as the fluid in the refrigerating system, thus effecting economies by avoiding the transfer of heat from one medium to another with attendant losses and inefficiencies. Typical applications will be discussed in detail below.

Typical Applications

Fermentation of sugars to **alcohol** evolves heat. This heat must be removed from the fermenting mass as it is evolved in order to prevent an undue rise in temperature that would affect adversely the efficiency of the operation. The quantity of heat is not great and its rate of evolution is slow. High temperature increases the amount of alcohol vapor carried away by the carbon dioxide gas evolved in the fermentation; and it may also profoundly affect the fermentation itself by changing the relative rates of growth of different yeast strains present.

Normally, the fermentation is started at about 70 F and kept below 100 F during the three or four days of its progress. Depending upon local conditions, the required cooling can usually be supplied by deep well water pumped through coils in the fermenters or sprayed on their outsides. Where this is unsatisfactory because of a limited supply of cooling water available, or its high temperature, supplementary cooling is sometimes supplied by refrigeration. The extent of this use of refrigeration is practically limited to emergency situations.

Alcohol evaporates from the fermenting mass and is carried away by the carbon dioxide evolved. This presents a special problem that may require refrigeration. The quantity of alcohol that can be recovered from the fermenter gas is great enough to justify washing all gas with water before it is vented. If the gas is to be recovered for sale as either liquid carbon dioxide or dry ice, further purification beyond water washing is required. The several methods employed include washing with sulfuric acid or with a solution of potassium permanganate; adsorption of

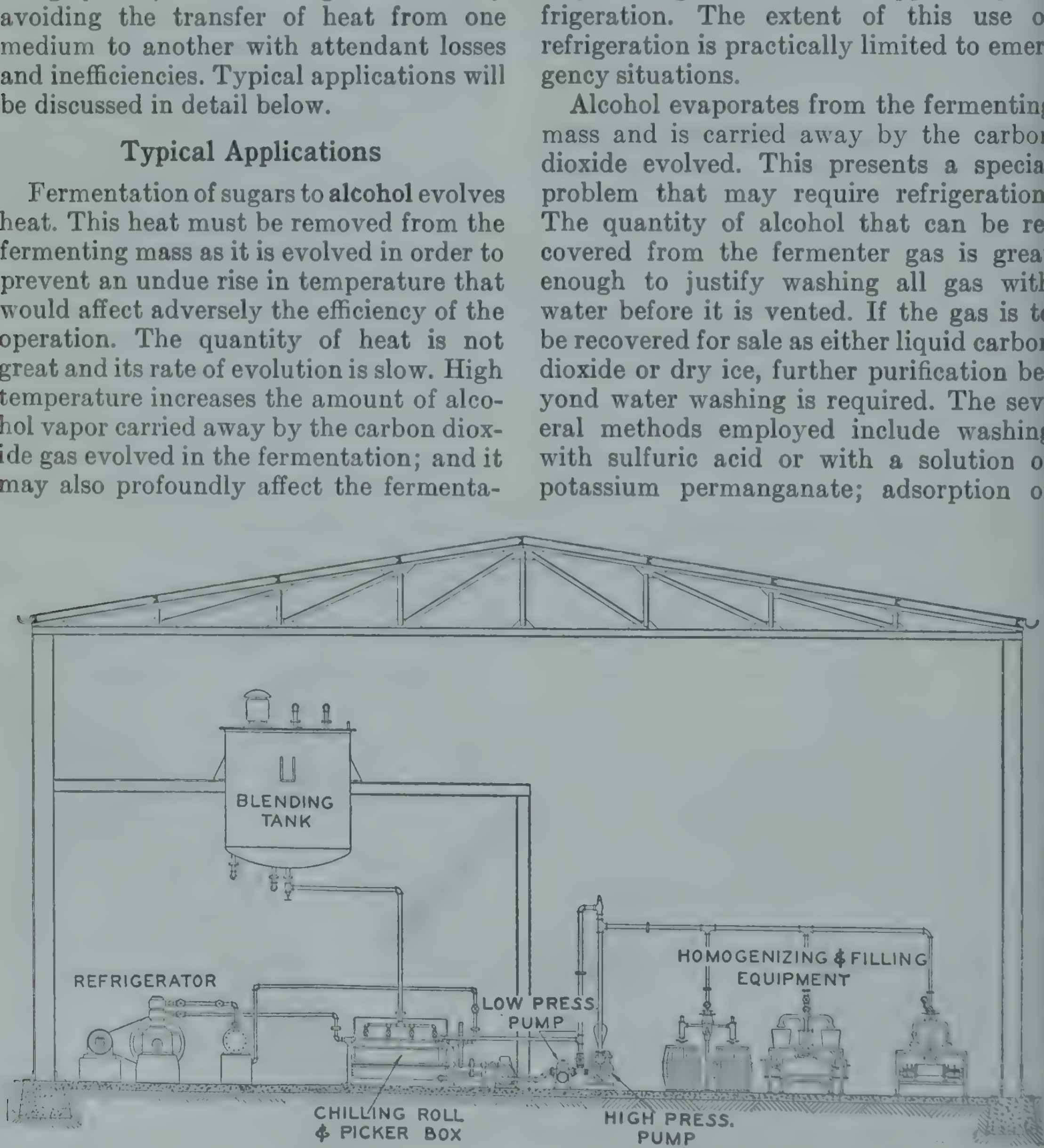


Fig. 1. Vegetable Oil Shortening Plant.

mpurities by silica gel or activated charoal; and combinations of these purifying teps supplemented by compression and ooling. Refrigeration is frequently employed to reduce the temperature of the dsorption medium used to increase its fficiency.

Production of **bleaching powder** and of **alcium hypochlorite** requires refrigeration or the control of the reactions involved. Bleaching powder is prepared by the reaction of gaseous chlorine as it comes from he electrolytic cells with hydrated lime. The basic chemical reaction is:

$$Ca(OH)_2 + Cl_2 = CaOCl_2 + H_2O$$

The product, chloride of lime, undergoes further reaction when dissolved in water and forms calcium chloride and calcium hypochlorite, thus:

$$2\ CaOCl_2 = CaCl_2 + Ca(OCl)_2.$$

The reaction of hydrated lime with chlorine releases heat but must be cooled (below 45 C (113 F)) to prevent decomposing the product. Hence, to increase the output of bleaching powder plants, the cement floors of the chambers in which the reaction is conducted are cooled by coils through which cold water or refrigerated brine is circulated. A typical old style bleaching powder plant consisted of a connected series of ten lead chambers ($20 \times 100 \times 7$ feet high) charged with hydrated lime and arranged for the passage of chlorine gas from the cells until it is completely absorbed. Several types of mechanical bleach machines now in common use overcome the shortcomings of these old plants.

Whereas the lead chamber plants required about 1400 sq ft of floor to produce a ton of bleaching powder per day, the much better contact obtained between gas and solid by the stirring effected in the mechanical machines gives them far higher capacity per unit of space. At the same time the high rate of reaction in mechanical bleach producers necessitates efficient cooling to prevent an undue rise of temperature.

Bleaching powder is gradually giving way to other more efficient materials for accomplishing the same purpose, especially liquid chlorine and calcium hypochlorite (marketed under several trade-marks, such as H.T.H. (high test hypochlorite)). Stable, crystalline calcium hypochlorite possesses oxidizing power (available chlorine), and hence bleaching power, nearly three times that of the same weight of relatively unstable bleaching powder. As noted above, bleaching powder is converted in solution in water into calcium hypochlorite. This reaction provides the simplest method of making the latter compound: The direct chlorination under pressure of a slurry of lime in water. Calcium hypochlorite can be forced out of solution in the resulting slurry, in which it is not very soluble, by the addition of salt. This procedure, however, yields a sludge which is difficult to filter, and consequently indirect methods which avoid this difficulty are preferred. Several of these have been devised and are now in operation. One is based on chlorinating a solution of equivalent amounts of lime and caustic soda and crystallizing from the chlorinated product a complex triple salt (calcium and sodium hypochlorites with sodium chloride) at a temperature of −10 C (14 F). At this temperature crystallization is complete and the filtration is much simpler than that of calcium hypochlorite ($Ca(OCl)_2 2H_2O$) which crystallizes at higher temperatures. After separation, the triple salt is converted into stable calcium hypochlorite by the addition of a chlorinated slurry of lime.

Another method of preparing calcium hypochlorite consists in passing chlorine gas diluted with air and carbon dioxide over solid sodium bicarbonate and dissolving the chlorine monoxide formed in ice water. The reactions involved are:

$$2Cl_2 + 2NaHCO_3 = Cl_2O + 2NaCl + 2CO_2 + H_2O.$$
$$Cl_2O + H_2O = 2HOCl.$$

The hypochlorous acid solution is neutralized with lime while being cooled by brine coils and the calcium hypochlorite recovered from the solution by spray drying.

Cellulose, the raw material for **rayon** and several important **plastics**, must undergo drastic chemical reactions in its conversion from its original filament form to the plastic compositions which permit it to be molded into shape or drawn into the fila-

ments of rayon. The peculiar chemical complexity of cellulose makes it highly reactive, and the common reactions employed in any of the usual transformations are likely to proceed too far unless carefully controlled. The result of lack of control, in the best case, may be loss of raw material, or finished product, or both; and in the worst case, may lead to destructive explosion and fire. Thus in all chemical processing of cellulose to form its derivatives, low temperatures requiring refrigeration are used to control reaction rate.

Production of rayon by the **viscose process** consists of the conversion of purified cellulose to cellulose xanthate, soluble in dilute caustic soda, and regenerating the original cellulose by coagulating the xanthate solution in an acid bath. The point of this process—as of others involving cellulose—is that conversion to xanthate destroys the original structure of the fiber and allows the cellulose to be shaped or formed as desired into filament or sheet before regeneration. (See Chap. 79.)

Water supply is the vital consideration in locating a viscose plant since large volumes are required for washing, cooling and air conditioning the plant. Additional quantities go into the processing solutions used. Normally the cooling requirements can be met by the use of cold well or river water, but emergencies are encountered when refrigeration is necessary to supplement this source of cooling. Consequently, rayon plants are usually designed with refrigerating machines to meet such conditions as well as to give an added factor of safety to ordinary operation.

Production of **cellulose sheet** (cellophane) and of sausage casings from viscose solution is identical so far as the basic process is concerned with production of rayon, millinery straw, and a variety of other products. Differences appear only in the orifices through which the solution enters the coagulating bath and the contacting method.

Cellulose esters—that is, compounds of cellulose with acids—form an important group of products useful as filaments, as transparent sheet, and as plastics. Their important common characteristics are their solubilities in organic solvents, their transparencies and the variations in properties that can be produced by variations in conditions of their formation.

Cellulose nitrate, the original synthetic plastic, also constitutes smokeless powder and guncotton, is the essential constituent of a large family of quick drying lacquers, and is the intermediate form of a once popular type of rayon. Because of its importance as an explosive, production of cellulose nitrate—nitrocellulose is synonymous—is discussed in detail in the section devoted to that subject. (See Chapter 56.) Minor variations in the process of producing its explosive forms yield the cellulose nitrate suitable for plastics, for lacquers, or for rayon. The differences between the explosive and the plastic lie principally in the extent of the nitration—strength of acid, time, temperature, in modifying agents added, and in the physical treatment needed to produce the desired final form.

Cellulose acetate forms the basis of lacquers, plastics, filaments, and transparent sheet. Each of these applications depends on its solubility in and compatibility with solvents and plasticizing agents. The process of manufacture consists in treating purified cellulose (preferably cotton) with a cold (40 F) mixture of acetic anhydride and glacial acetic acid with or without the addition of a small amount of sulfur dioxide ($\frac{1}{2}$ of 1 percent of the reacting mixture). Refrigeration is used here.

The product of this reaction is a solution of cellulose acetate in acetic acid from which the product can be recovered by dilution with water. The solution is allowed to age before precipitation. The cellulose acetate thus made (a flocculent mass) is dissolved in acetone for spinning or mixed with suitable plasticizers for molding. The spinning operation consists in forcing a solution of cellulose acetate in acetone through a fine spinneret into a current of air which quickly evaporates the acetone leaving the fine filament of cellulose acetate itself.

Recovery of the unconsumed acetic acid from the dilute form coming from the acetylating reaction and of the solvent acetone from the spinning is crucial to the success of the process. Several types of recovery processes are available for both operations. Recovery of acetone usually

employs both an adsorbent substance (activated charcoal) and low temperature (refrigeration) in recovering and concentrating the solvent from relatively large volumes of air.

Chlorine is most widely used in industry in liquid form. When pure and dry the liquid can be safely handled in steel cylinders without fear of corrosion. The boiling point of liquid chlorine is −34.6 C (−30.3 F), and, at ordinary atmospheric temperatures, its vapor pressure is substantial (6.62 atmospheres at 20 C (68 F)).

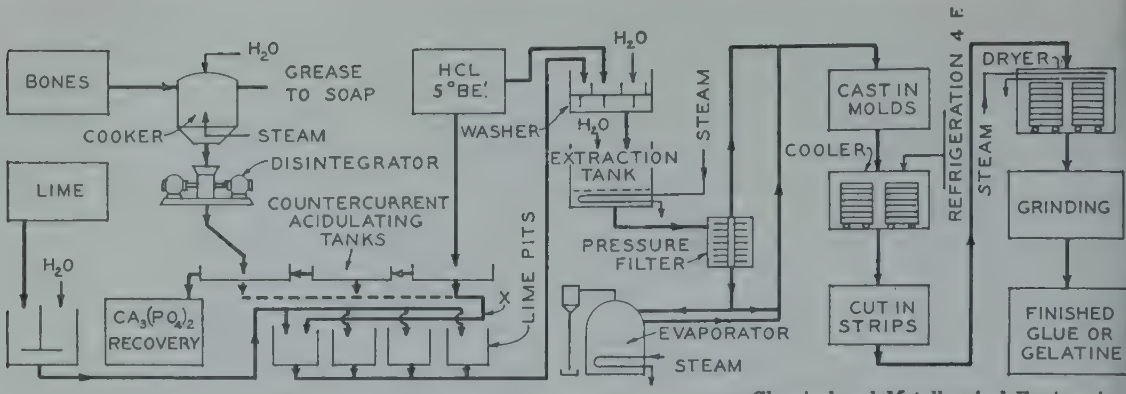
The liquefaction of the chlorine gas obtained from electrolytic cells is accomplished by a combination of cooling and compression. One of the important reasons for this is the highly corrosive nature of the moist gas and the consequent difficulty in handling it in conventional compressor equipment. A special compressor (Nash Hytor) employing a rotary piston in an ovoid casing sealed with concentrated sulfuric acid is generally used for this compressing operation. The gas from the cells is drawn by the compressor at slight suction through a stoneware tower where it is dried by washing with sulfuric acid. The dry gas is then compressed to about 25 lb gage (at which pressure the Nash compressor functions efficiently) and cooled to liquefying temperature (below −10 C (+14 F)) by direct contact with the expansion coil of a refrigerating machine. Preferably, the fluid used in the refrigerating system is carbon dioxide since any leakage of this gas would do no more than dilute the chlorine. Ammonia reacts violently with chlorine and, if it is employed, cooling of the chlorine is accomplished through brine coils to insure against any possible intermixing of ammonia and chlorine in case of accidental leakage. The latent heat of chlorine is approximately 120 Btu per lb.

Distillation and **solvent recovery** operations, particularly those involving liquids having low boiling points, can advantageously use refrigeration. Typical of liquids of this kind are ether, methyl and ethyl chlorides, carbon disulfide, carbon tetrachloride and others. In the production of these compounds and their purification by distillation, condenser temperatures below those attainable with ordinary cooling water are required to prevent undue loss by evaporation. Consequently, refrigeration is employed to prevent loss both in manufacturing plants and others where highly volatile materials are used. The special case of solvent recovery where the vapor of the material to be recovered is mixed with air is more economically solved by adsorbing the desired vapor from the air mixture with highly adsorbent activated charcoal, silica gel, alumina gel or like product. These adsorbents have the important property of removing relatively small amounts of valuable material from large volumes of air economically, and often require to be cooled themselves during their adsorption cycles to maintain their efficiency.

The manufacture of many **synthetic dyes** utilizes the so-called diazo reaction which must be carried out at temperatures at or below 40 F. A solution of sodium nitrite is added cold to a cold solution of a dyestuff intermediate, such as aniline, in dilute hydrochloric acid. The reaction forms a highly unstable diazo compound, which spontaneously decomposes at ordinary temperature. The cold diazo solution is mixed with one of another appropriate dyestuff intermediate to form a stable azo dyestuff. The solutions must be kept cold until the dyestuff is formed. This is usually accomplished by the addition of ice directly to the solutions in wooden tanks (since the usual metals affect the reaction adversely). The effectiveness of present day stainless, corrosion-resistant alloys is encouraging dye manufacturers to revise their equipment and to use brine to cool the solutions instead of ice.

The diazo reaction may in certain cases produce an insoluble dye which consequently cannot be applied to cloth in the usual manner. To get around this difficulty the cloth is treated with one of the intermediates necessary to form the desired dye and is then run through a cold diazotized solution of the other. Thus the insoluble dye is formed in the actual fiber in the refrigerated bath. Such developed dyes are especially fast and are used largely on cotton fabrics to obtain special effects.

Gas purification occasionally employs refrigeration methods to remove impurities which might prove troublesome in distribu-



Chemical and Metallurgical Engineering

Fig. 2. Glue and Gelatine.

Note: Manufacture of glue and gelatine differs largely in that poorer grades of raw materials and higher extracting temperatures are used for the former. Glue is more completely hydrolyzed than gelatine. Instead of bones, skins, hides, sinews, hide scraps, fleshings, fish stock, etc., may be used, in which case, after washing, they are introduced at *X*. Usually three extractions at temperatures from 60 to 75 C are used. The last extract requires concentration before molding.

				To produce:	
Bones	3.03 tons	Steam	400 lb	Gelatine	1 ton
Hydrochloric acid	1.14 tons	Electricity	55 kw hr	$Ca_3(PO_4)_2$	1.67 ton
Lime	0.76 tons	Direct labor	6 man hr	Grease	0.08 ton

tion mains, or to recover valuable products. Removal of easily liquefied constituents from natural gas before it is put into pipelines for transmission to more or less remote points is necessary to prevent clogging of lines. This is usually accomplished by compressing the gas so that needed cooling can be supplied by the cooling water available. Purification of manufactured gas employs chemical reagents and solvents to accomplish the major separations. However, certain special cases arise in practice where cooling below temperatures available with cooling water alone are necessary to complete the removal of some constituents that would otherwise cause trouble in the distributing system. Refrigeration has also been used in the drying of illuminating gas.

Gelatine manufacture requires refrigeration in the final stages of the process. The gelatine solution is prepared by boiling hides, hide trimmings, bones and sinews with water, followed by concentration of the solution in a vacuum evaporator. The resulting solution is cooled to set it to a jelly that can be subsequently dried. Usually refrigeration is necessary to solidify the jelly and the air used for drying the jelly must be dehumidified so that the drying operation can be conducted at a low temperature. Manufacture of **glue** is similar to that of gelatine and involves similar applications of refrigeration. In the industries where glue and gelatine are used, air conditioning is the general rule.

Margarine manufacture employs refrigeration to solidify the final product. Oleomargarine is essentially an emulsion of cultured milk in edible fats of the proper consistency and composition. This emulsion is formed warm and chilled at once to maintain its composition uniform throughout. Various mixtures of fats are used in modern margarine manufacture which originally employed only beef fat. Most common are hydrogenated vegetable oils, the composition of the mixture and the extent of the hydrogenation being adjusted to give a final fat having the properties of butter fat. Into the blended fats is emulsified a cultured milk, and vitamins and salt are added. As soon as formed, the emulsion is solidified on chilled rolls.

Mercerizing cotton cloth is chemically similar to the initial step in the preparation of viscose solution for rayon manufacture. The cloth is treated with a cold solution of caustic soda and then washed and dried under tension. The resulting fabric possesses enhanced luster and greater tensile strength than the original. The tempera-

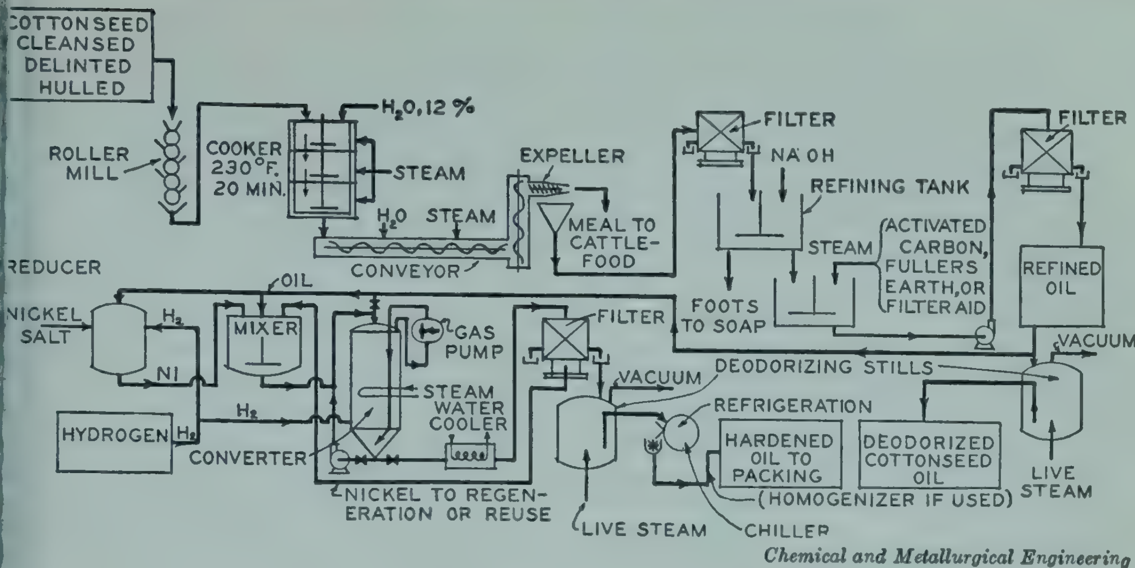


Fig. 3. Cottonseed Oil, Refined and Hydrogenated.

Note: This flow sheet combines processes not ordinarily performed in the same plant. The first processor may produce crude oil, for example, while a second will refine and hydrogenate it. Oils hydrogenated for food are deodorized after hardening.

Refined and Deodorized Oil

Cottonseed	55	lb	Per gal oil
NaOH	0.1	lb	
Water (cooling)	20	gal	
Steam	15	lb	
Direct labor	0.015	man hr	

Hydrogenated Oil

Refined cottonseed oil	0.134	gal	Per lb hardened oil
Nickel	0.00075	lb	
Hydrogen	0.75	cu ft	
Water (cooling)	0.6	gal	
Steam	0.5	lb	
Direct labor	0.0006	man hr	

ture and the concentration of alkali used are selected to give the result desired. At lower temperatures (from normal room temperatures down to the freezing point of water are employed), the concentration of the caustic solution can be lower to accomplish the same result. Consequently it is practice to use refrigeration to keep the solution cold and increase its effectiveness. Variations of temperature and concentration of alkali give the operator some choice in the qualities of the product.

Nitration is probably the most important chemical reaction requiring temperature control, since not only is it likely to prove costly and hazardous if uncontrolled, but the direct and indirect value of its products is especially high. Nitric acid, the agent used in nitrations, possesses a dual character; it is both a nitrating and an oxidizing agent. To control its avid reactivity, the temperature at which it acts must be carefully held within narrow, prescribed limits. This is particularly necessary since the temperature of the reaction mixture tends to rise rapidly from its own, self-generated heat. Some plants are fortunate in having well water cold enough to use as the cooling agent in their nitrators, but many must depend on refrigerated brine at least to supplement natural cooling.

Typical is the nitration of benzene to nitrobenzene—from which aniline and its huge family of dyes and pharmaceutical products are derived. In the reaction about 855 Btu are evolved for each pound of nitrobenzene formed. Obviously this large amount of heat must be rapidly removed to prevent an undue rise of temperature. Since this must be done without dilution of the mixture, the acid-proof surfaces of the containing vessel must be kept substantially below the operating temperature. Cooling coils are introduced to extend the cold surface and the temperature of the cooling water or brine adjusted to fit.

Similar precautions must be taken in making nitroglycerol, nitroglycol and other explosives, and in making nitrocellulose and a wide variety of other nitrated com-

pounds. A more detailed discussion of this subject will be found under the heading "Explosives." (See Chap. 56.)

The relation of temperature to solubility is utilized in many industrial operations to effect separations otherwise difficult or impossible. Some of these applications are quite simple but others involve the most exact applications of the finest physical chemistry.

Among the simplest, but also largest scale, separations by cold are the "winterizing" of fatty animal and vegetable oils, and the corresponding treatment of petroleum lubricants. **Cottonseed oil**, particularly, contains substantial amounts of solid stearin in solution, but because of stearin's relatively low solubility at low temperatures, the oil tends to become cloudy and unsightly when cooled. To overcome this, refiners "winterize" their product by storing it at temperatures of +5 to −10 C (+40 to +14 F) long enough to allow this separation to occur and then filtering off the clear oil. The separated solid stearin is compounded with hydrogenated oil to form vegetable lard. In this compounding operation, the various fats and oils required in the final mixture are blended warm and then chilled suddenly on a refrigerated drum to insure against separation of the various constituents.

Refining of **petroleum lubricants** involves a step indentical with winterizing cottonseed oil and performed for the same purpose. The difference between the two operations is that appearance of lubricating oil is of negligible importance, but its fluidity at low temperatures is vital to its service. Constituents are frozen out which would unduly raise the viscosity of the oil if not removed. The petroleum industry also employs refrigeration in the separation and purification of **paraffine waxes.** (See Chap. 57.)

Recently developed in petroleum refining is the use of liquid propane. This substance, ordinarily a gas (B.P. −48.1 F), is the most plentiful and least costly material next to water around a modern oil refinery. Its value depends upon the peculiar changes in its solvent power at different temperatures. Between its boiling point and its critical point (643 lb per sq in. and

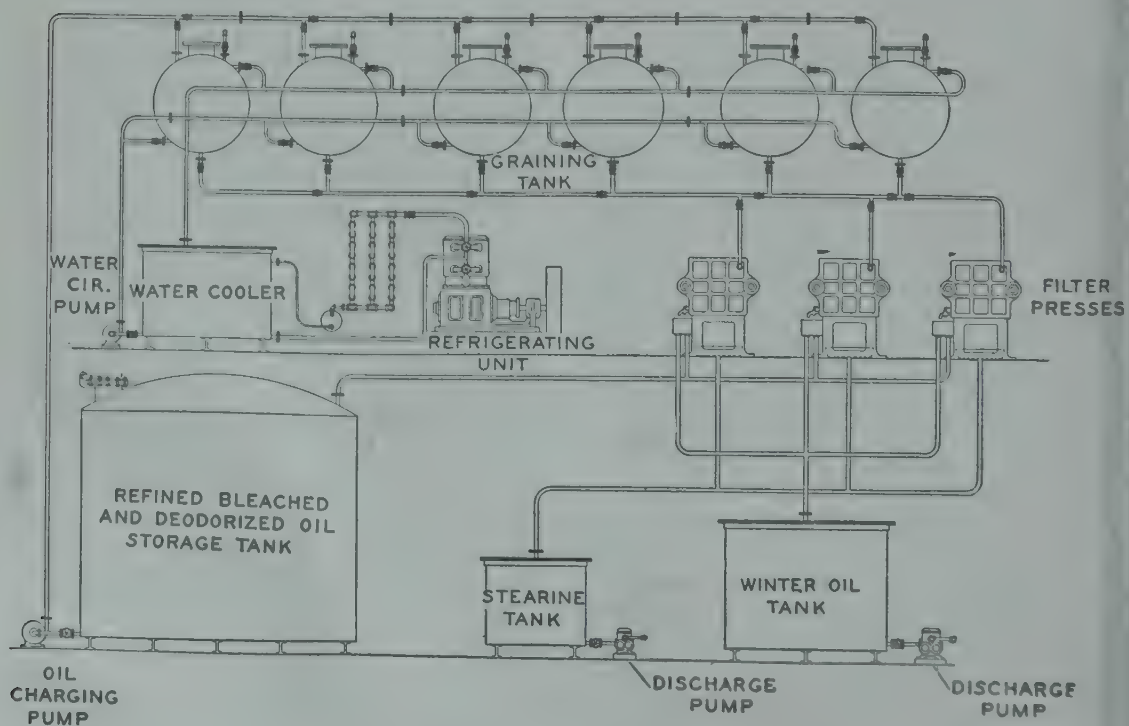


Fig. 4. Winter Oil Plant.

12.2 F), liquid propane behaves as if it ere a whole series of different solvents. sing it over this range the oil refiner can mplify substantially the processing of his bricating oils. This operation requires the andling of propane under a variety of contions by equipment of the refrigeration pe and also the final recovery of the solent.

Practiced on a scale tiny by comparison ith petroleum refining, but none the less nportant in its field, is the freezing out of ts from alcoholic solutions of **perfume oncretes.** Delicate odors of certain flowers e absorbed by thin layers of certain fats pread near the flowers. The product, nown as a flower concrete, is the form in hich many flower odors reach the perumer. In preparing the required essence om the concrete, the perfumer dissolves ie latter in purified alcohol and then hills the solution to throw out as much as ossible of the fat, the presence of which the finished perfume would be deleterius. The freezing out is conveniently acomplished by the use of dry ice, and at the emperatures thus attained the solubility f fat in alcohol is practically negligible. his method of preparing flower essences used in making special odors that would e injured by the higher temperatures reuired by the more usual techniques.

An analogous application of intense cold the **dehydration of ether** by cooling it dry ice temperature. This is practiced n a small scale in the laboratory recovery f used ether to avoid the fire hazard of istilling this highly combustible and volale solvent.

In the control of solubility, a vital process in industry, it is usually advantageous use the vapor of the solvent itself as the efrigerating fluid and refrigerating mahinery must consequently be adapted to ie peculiar conditions of each application this field. Temperatures involved vary ith the requirements of the individual roblem over a wide range, sometimes beig actually above those of the atmosphere. hus we have the strange paradox of "reigeration" at high temperature, where its sefulness is in the precise control of temerature at a required level.

Processes of crystallization separate and purify the constituents of a solution. A simple case is the crystallization of salt from brine. **Vacuum crystallization** of salt is common practice. The hot, concentrated brine is subjected to vacuum in the evaporator, and this simultaneously cools and concentrates the solution to the point of crystallization by evaporation of part of its water. Its advantage lies principally in avoiding transfer of heat through surfaces that may become coated with crystals. The vacuum must be produced by a high capacity unit, and hence a condensing steam-jet pump is usually used.

More complex is the separation of pure salts from such mixtures as the **potash minerals** and a variety of crystallizations in which the amount of combined water in the product can be varied by fixing the temperature and concentration at which crystallization occurs. Natural potash salts occur in complex minerals containing salts of sodium and magnesium, among others. To separate the potash in form pure enough for use, all factors—temperature, concentration and composition of solutions—must be closely controlled. This involves a range of temperatures which may be produced by customary refrigeration methods, by application of vacuum or even by heating as requirements of the particular operation dictate. This industry, located in California and New Mexico, produces several hundred thousand tons of potash salts and borax annually.

The other important case of crystallization is represented by the several **hydrates** of **sodium sulfate** and of **sodium carbonate.** The former can be crystallized with 56 percent of water of crystallization, with 47 percent, or with none at all, and the form of its crystals can be modified depending upon temperature and concentration. Four types of sodium carbonate crystals can be similarly produced, containing 63, 54.5, 14.5 and 0 percent of water of crystallization. These two salts are typical of many which are produced in chemical plants in a variety of forms depending upon the conditions of crystallization. Often refrigeration is required to secure the necessary uniformity of product.

The Steffens process for recovering crystal sugar from the molasses of **beet sugar**

refineries employs substantial amounts of refrigeration. The molasses obtained as the final mother liquor from crystallizing sugar from beet juice can no longer yield sugar crystals by ordinary methods. Most of its sucrose content can be recovered in salable form if the sugar can be separated from impurities which act as protective colloids in preventing crystallization. In the Steffens process, separation is accomplished by precipitating the sucrose from the cold, diluted molasses by the addition of lime slurry. Precipitation occurs most favorably at a temperature of 10 C (50 F) to which the molasses, diluted to a concentration of about 7 percent sucrose, is cooled by refrigeration before the addition of lime. The precipitate is tribasic calcium saccharate which is filtered off and returned to the refining process at the carbonation station. Here it replaces part of the lime required in clarifying the juice entering the process. It gives up its sugar content to the juice when carbon dioxide is added to precipitate the lime along with impurities in the juice. Total recovery of sugar from the beet is 85 to 88 percent of that originally present.

Refrigerants

The manufacture of **synthetic ammonia**[1] is essentially the compression of a hydrogen-nitrogen mixture involving three parts hydrogen and one part nitrogen to an elevated pressure usually on the order of about 300 atmospheres.

This mixture, after being cooled and purified is passed into an ammonia converter where, at an elevated temperature and in the presence of a special catalyst, the two gases are made to unite and form ammonia (NH_3).

The system is essentially a cyclic one and the gases are passed through the catalyst many times. Approximately one-half of the ammonia content of the circulating gases is condensed out by water cooling and the remaining half in a flooded type more or less standard ammonia refrigerating cycle. In order to remove as much as possible of the ammonia content of the circulating gases, a low temperature of about -22 F is desirable. This involves the maintenance of an evaporating temperature at about the atmospheric pressur level, which for ammonia is a rather ineffi cient level because the suction pressure i quite low.

Minor concentrations of water and oi vapor are also condensed out in the abov described cycle, so the process involves th purification step, as well as merely the re moval of ammonia by low temperatur condensation.

In the manufacture of **liquid and soli** CO_2, the CO_2 gas is compressed to approxi mately 1000 lb per sq in., where conden sation is effected usually by water in a ordinary condenser. Because the critic temperature of CO_2 is rather low (87 F) obviously water at or near this tempera ture cannot be used effectively, and mos operators prefer cold well water for th condensation of the CO_2 gas, the colder th better.

Where cold well water or other reason ably cold water is not available, some dr ice plants use what is called the binar cycle where condensation of the CO_2 i effected by ammonia refrigeration. Her the carbon dioxide is condensed by a sec ond refrigerant, usually ammonia, and th condensing pressure of the carbon dioxid is reduced to 600 lb per sq in. or lowe Although the lower pressure represents saving in power, the total overall powe requirements are much the same as ordinary water were used for condensation because power is required to operate th ammonia cycle.

It is most interesting to note that a dr ice plant uses all the ordinary elements o a CO_2 refrigerating cycle plus a few whic are special in that the refrigerant itself en ters as gas at one end and leaves as soli at the other (see Chapter 53).

As the CO_2 gas enters the compressio system saturated with water vapor, a dry ing agent such as silica gel, alumina gel, o calcium chloride is necessary to preven the system from freezing up and to permi the production of pure dry ice. Drying i usually done between the second and thir stages of compression although it can als be done at the 1000 lb per sq in. leve after the third stage.

In a normal refrigerating cycle, the cir culation of a small amount of compress

[1] Section by R. J. Quinn.

ıbricating oil in the refrigerant causes no articular trouble. In a dry ice system, owever, all oil must be removed to preent poisoning of the silica or alumina gel nd to keep it out of the final product, quid or solid CO_2 as the case may be.

A well operated plant will remove all but he most minute traces of oil, water and ther contaminants in the final product, nd considerable apparatus and operating kill are required to effect this removal.

In the manufacture of **methyl chloride**[2] ıechanical cooling is used only to a limited xtent. Refrigerated brine is used as the oolant in the auxiliary vent condensers. t is desirable for that purpose in that it ıinimizes the vent losses in the condensaion system.

Plants for the manufacture of **liquid ulfur dioxide**[2] may be divided into two eneral types. In the first the gas from the ulfur burners is absorbed in water or other bsorbent. Refrigeration plays only a ıinor part. The SO_2 gas distilled out of he absorbent after removing the water is ver 90 per cent SO_2 by volume. This gas, fter compressing, is readily condensed in water-cooled condensers and the blow-off from these condensers is small in volume and is returned to the absorbers. Some plants use a refrigerated condenser between the main water-cooled condensers and the absorbers to remove additional SO_2 as liquid, which has the advantage of saving the recycling of the SO_2 condensed in the refrigerated condenser.

[2] Section by A. H. Eustis.

In computations, 0.08 ton of refrigeration may be used for each 1,000 lb of SO_2 produced per day. The refrigerated condenser is kept at approximately 32 F.

In the second type of plant, the gas from the burners is compressed without going through an absorption cycle; refrigeration may be much more important. This varies in different plants and depends on the final disposition of the non-condensed gases.

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56. POWDER, EXPLOSIVES, AND PYROTECHNICS

THE use of refrigeration in the explosives and allied industries is a means to an end rather than a principal part of the industry itself. As is the case in so many other industries, the ratio of total cost of installation of plant and chemical equipment to the cost of the refrigerating equipment is out of proportion to the relative importance of the latter.

The explosives industry could not operate without refrigeration. It is needed principally to prevent the temperature of materials being processed from rising above the level of safe or efficient operation. The necessity for such **accurate temperature control** is due to the peculiar properties of explosive substances. In order to clarify this necessity, a brief description of some of these properties will be given.

Most explosives are made up of materials in a condition of unstable equilibrium. They decompose very rapidly or otherwise undergo an almost instantaneous chemical reaction, evolving large volumes of gases under high pressure and temperature, when this equilibrium is disturbed. A mechanical analogy of this chemically unstable equilibrium would be a truncated cone or pyramid balanced on its small end, ready to fall over if pushed too far to one side. This property of **chemical instability** is common, and the rules controlling all chemical reactions apply to explosions. In general, the higher the temperature, the greater is the speed. Many chemical processes are doubled in speed by an increase in temperature of less than 20 F. This effect of temperature on reaction speed can be shown as

$$\frac{R_{t_2}}{R_{t_1}} = (2)^{t_2 - t_1/20}$$

where R_{t_1} and R_{t_2} represent the speed of explosive reaction at the temperature t_1 and the temperature t_2 respectively, and $t_2 - t_1$ represents the rise in temperature. For example, the ratio of the explosion speed at a temperature of 200 F to the explosion speed at a temperature of 100 F will be calculated as follows:

$$\frac{\text{Rate at 200 F}}{\text{Rate at 100 F}} = (2)^{200-100/20} = (2)^{100/20}$$

$$= (2)^5 = 32.$$

This shows that the explosion would proceed 32 times as fast at 200 F as it would at 100 F.

Another peculiarity of explosive reactions is the fact that **large amounts of heat are liberated.** As an explosion starts, the heat produced goes partially toward heating the remaining explosive material to a high temperature. This in turn causes the explosion to proceed still more rapidly. Therefore, explosive substances must not be allowed to heat unless an explosion is desired.

Although explosives may be grouped into numerous classes depending upon purpose of the classifier, the most generally used classification from the viewpoint of military needs is into two groups, **low ex-**

CROSBY FIELD, Co-Author Chapter 56. Born 1889 in Jamestown, N.Y. Educated at New York University, BS, 1909; Cornell University, ME, 1912; Union College, MS Elec. Engrg., 1914. Formerly, Consulting Engr., 1914–15; Chief Engineer, Standard Aniline Products, Inc., 1915–17; Eng. Manager National Aniline and Chemical Co., 1919–23; Vice President, Director, and Secretary, Brillo Mfg. Co., 1923–45.

Author of numerous papers on engineering specialties; contributor to *Refrigerating Engineering* and early editions of ASRE Data Books; Co-author Chapter 51, 1946 Applications Volume, ASRE Data Books.

Fellow, ASME, AIEE, AAAS, and ASRE; ASRE President, 1938.

Awarded the Legion of Merit for his contributions to safety.

At present, President, Flakice Corporation, Brooklyn, N.Y.

CLARK SHOVE ROBINSON (deceased), Co-Author Chapter 56. Born 4/88; died 5/47. Educated at Mass. Inst. of Technology, BS, 1909; MS, 1915. Instructor, M.I.T., 1915–19; Asst. Professor, M.I.T., 1919–1947; President, Boston Post of Army Ordnance, 1937–39; Member of Planning Board of Reading, 1931–37; Reserve Officer, Colonel, as consultant on chemical engineering, 1920–47.

Author of books on "Thermodynamics and Fire Arms"; "Explosives Chemistry for Safety Engineers"; "Explosives—Their Anatomy and Destructiveness"; Co-Author, Chapter 51, 1946 Applications Volume, ASRE Data Books.

Awarded the Legion of Merit for his contributions to safety.

plosives and high explosives. The latter is in turn divided into two subgroups, **detonating explosives** and **initiators.**

Low explosives or propellants are chemical compounds or mixtures of materials which contain within themselves combustible materials and materials containing the oxygen needed for their combustion. Varying rates of burning within wide ranges are obtainable by changing the constituents or the pressure conditions under which the burning takes place. The most rapid burning or deflagration frequently produces results overlapping somewhat the results obtained by high explosives. Low explosives are most frequently used as propellants to produce the relatively slow liberation of energy required to push the projectile out of a gun. The usual rate of burning of smokeless powder in the gun is from 10 to 20 ft per sec.

Detonating explosives do not function by burning, but when subjected to the shock of explosion of a suitable initiator, liberate energy at a tremendous rate. The detonating rate varies from 15,000 to 25,000 ft per sec. They are used in shell and bomb bursters for military purposes, and for demolition. Common examples are TNT (trinitrotoluene) and dynamite.

Initiators, sometimes called primary explosives, explode or detonate when heated or when subjected to shock. They are used, as their name implies, to initiate explosion in detonating explosives or even in low order explosives. They are the link in the explosives chain between mechanically or electrically applied force and liberation of chemical energy. Examples are mercury fulminate and lead azide.

Most explosives are made by nitration, during which large quantities of heat are liberated. Unless this heat is removed as fast as produced, the temperature of the nitrating mixture will rise and the mixture may ignite or explode. The control of temperature in the manufacture of such substances is therefore vital. Available water may be inadequate as to supply or too high in temperature. Under such conditions, refrigeration is essential.

The manufacture of **smokeless propellent powder** introduces another use of refrigeration. Smokeless powder is made principally from nitrocellulose, which in its original form looks like blotting paper or absorbent cotton, and which must be converted into a gelatinized substance resembling celluloid. This conversion requires the use of solvents which are usually volatile and inflammable. In most cases, ordinary cooling devices using air or tap

Table 1. Classification of Refrigeration Uses in the Explosives and Pyrotechnics Industries

- Temperature Control
  1. Control of physical properties of materials during processing
  2. Control of chemical reaction rate
     a. Industrial processes
     b. Storage of temperature-sensitive materials
        (1) Explosives
        (2) Chemicals
- Removal of Heat
  1. Chemical reactions
     a. Nitration
     b. Esterification
     c. Saponification
     d. Neutralization
  2. Physical processes
     a. Condensation of solvents and other vapors
        (1) Direct condensation
        (2) Absorption in solvents
        (3) Adsorption on carbon or other solid
  3. Frictional Heat
     a. Mixers
     b. Presses
     c. Cutters
- Removal of Water or other Solvent
  1. Air conditioning
     a. Manufacturing processes
     b. Magazines and other storage
  2. Drying
     a. Raw materials
     b. Intermediates
     c. Products
     d. Renovation

water are insufficient to condense the vapors of these solvents and recourse must be had to refrigeration. The gelatinized nitrocellulose is processed mechanically, and like all plastics, necessitates careful temperature control to insure the correct degree of plasticity, since this property is very sensitive to temperature changes.

The pyrotechnics industries make use of chemical substances which, while by themselves, are not explosive, but which become so on mixing. Many of them contain finely divided **metal powders** such as powdered iron, aluminum, or magnesium. These

metal powders are readily oxidized in the presence of air, and by water and water vapor, if the temperature is allowed to go too much above room temperature. To avoid difficulties with such mixtures, therefore, air conditioning is necessary to keep the air in contact with such mixtures cool and dry. This same requirement is also met in ammunition plants where explosives are exposed to the air during processing.

The Smokeless Powder Industry

The manufacture of smokeless powder by the conventional process is divided into stages: (1) Nitrocellulose, (2) green powder, (3) solvent recovery, (4) finishing.

In the **green powder** area of a smokeless powder plant, the constituents of the powder are blended in a device called a mixer. This is a modified dough mixer with slowly moving sigma-shaped blades. In this mixer the solid constituents of the powder are mixed with alcohol and ether, both of which are volatile, producing highly inflammable vapors. It is necessary, therefore, to keep the temperature from rising in this mixing machine, and the customary upper limit for the permissible temperature is 70 F. In order to maintain a temperature below this point in the mixture, it is necessary to circulate brine, usually carried at about 38 F, through a surrounding jacket. A 10-ton refrigeration compressor is used in a typical mix house unit in a smokeless powder plant. The cooling fluid is sometimes a strong alcohol rather than brine.

After the mixing operation, the material goes through what is called maceration, which is another mixing process operated under somewhat the same conditions as in the previous mixer, except that the temperature of the refrigerated alcohol in the cooling jacket is lower, usually in the vicinity of 26 F. It is extremely hazardous to attempt to run either the mixer or the macerator without refrigeration, since heating of the mixture due to friction not only causes evaporation of the volatile solvents, but could result in explosion of the mixture itself.

One of the constituents used in many smokeless powders is a chemical called diphenylamine. This chemical is dissolved in ether before the ether is added to the mixture in the mixer, and the tank in which the dissolving takes place must be cooled by refrigeration. It is customary to use the refrigerated alcohol coming from the mixer houses and from the macerator houses for the purpose of cooling the diphenylamine dissolving tank.

The green powder which comes from the first part of the powder manufacturing process contains alcohol and ether which must be removed in the solvent recovery and finishing processes. The first part of this removal takes place in what is called the solvent recovery equipment where warm gases, often inert, are blown through the green powder causing the ether and some of the alcohol to evaporate. These gases are then blown through containers where the solvent is partially condensed out. As ether is highly volatile, a low temperature must be maintained in the condenser. It is customary to keep this low temperature by using refrigerated water at about 38 F. Some plants use a steam-jet refrigeration unit for this purpose. The characteristics of such a unit are typically as follows:

Temperature of chilled water, 38 to 48 F, with return water at 48 F; 1640 gal per min. Temperature of condenser water handled, 80 F, with water leaving at 91 F; 2100 gal per min.

Steam pressure for boosters, 30 lb per sq in.

Steam pressure for steam jet pumps, 175 lb per sq in.

Steam consumption for booster, 7100 lb per hr.

Steam consumption for pumps, 300 lb per hr.

Chilled water pumps, capacity 4000 gal per min at 90-ft head, requiring 120-hp motor drive.

Chilled water booster pumps, at 45-ft head, requiring 50-hp motor drive.

Condenser water pumps, capacity 4500 gal per min at 95-ft head, requiring 120-hp electric motor drive.

The ether which is recovered in the **solvent recovery system** and that which is manufactured at the plant to replace loss must be kept well below its boiling point, which is 95 F. In summer chilled water must be circulated through the ether storage tanks and in the ether vapor condenser.

The Nitroglycerine Industry

Nitroglycerine, a very sensitive and powerful high explosive, is made by treating purified glycerine (dynamite glycerine), with a mixture of nitric and sulfuric acids. A large amount of heat is liberated in this process (nitration), and if this heat is allowed to remain in the mixture, the temperature will rise to the explosion point. By removing liberated heat as fast as produced by cooling coils submerged in the mixture, temperature is kept at a safe point. At the start of the nitration, brine enters the coils at about 0 F and should be held at about that temperature level throughout the nitration period. Glycerine is slowly added to the mixed acid in the nitrator, so that the temperature in the mixture remains in the vicinity of 40 F. If, by any chance, the refrigerating system fails and the temperature of the nitration mixture starts to rise, the whole mass is dumped as rapidly as possible into a large tank of water, in order to stop the nitration.

Refrigerating units used for this job may consist of two-stage ammonia compressors, of possibly 100 hp. It is also customary to provide an emergency system for circulating brine, using compressed air.

Pentolite and Other Explosives

Pentolite, one of the modern high explosives, is a mixture of trinitrotoluene, otherwise known as TNT, and the explosive pentaerythritoltetranitrate, usually called PETN. This is made by subjecting a chemical substance called pentaerythritol to a nitration process, where it is brought into intimate contact with very concentrated nitric acid. This nitration must be carried out at a temperature from 40 to 50 F, requiring circulation of brine in a jacket in the nitrating apparatus, at a temperature between −10 F and +5 F.

After the PETN is manufactured, it is then made into pentolite by dissolving in acetone, and mixing this solution with the proper amount of TNT also dissolved in acetone, which solution is carried at moderately high temperatures. The pentolite is crystallized from the acetone solution by mixing the solution with refrigerated water.

Diazodinitrophenol

Diazodinitrophenol, usually called Dinol, can be made by mixing picramic acid with sodium nitrite at a temperature only slightly above the freezing point of water. In order to maintain this low temperature, it is necessary to have the mixing apparatus jacketed with brine at a temperature in the vicinity of 32 F, making sure that the contents of the apparatus are thoroughly stirred at all times to bring them into close contact with the cool walls of the container.

Cyclonite

Cyclonite, or hexogen, is another of the newer high explosives. It may be made by nitrating a material called hexamine, at a temperature of about 68 F. In order to maintain this temperature, some sort of refrigerated cooling fluid is needed. In another process for manufacturing this high explosive, hexamethylenetetramine is treated with strong nitric acid at about room temperature and then cooled by external refrigeration to about 32 F and allowed to react at that temperature.

Nitrosoguanidine

Nitrosoguanidine is an explosive which is sensitive to shock, strong acids, or moderately high temperature, resembling in its properties, to some extent, fulminate of mercury and lead azide. It is made by treating nitroguanidine with ammonium chloride and zinc dust, maintaining approximately room temperature until the end of the reaction, when it is cooled to 32 F or below by means of refrigerating fluid in a jacket around the apparatus. The nitrosoguanidine crystallizes from the resulting solution when allowed to stand for several hours at 32 F.

Nitroguanidine

Nitroguanidine, which is one of the materials used in making nitrosoguanidine, and which also can be used as one of the constituents of flashless, smokeless powder, is made by dissolving guanidine nitrate in concentrated sulfuric acid under such conditions that the temperature does not rise above 50 F, requiring either refriger

ted water or brine in the cooling coils of he apparatus. The nitroguanidine is then recipitated from the mixture by diluting ; with water at a temperature of 32 F, reventing the temperature from rising bove that point by adequate refrigeration.

Iitrourea

Nitrourea, which is a powerful explosive ıot much used at the present time, is nanufactured by dissolving urea nitrate in oncentrated sulfuric acid while the temperature of the resulting mixture is kept below 32 F. On dilution, the nitrourea eparates out, and can be filtered off. The mpure material is then dissolved in hot lcohol, from which the purified material s obtained by crystallization on chilling to ı low temperature.

Jrea Nitrate

Urea nitrate, which is a raw material for the manufacture of nitrourea, is made by adding strong nitric acid to urea which has been dissolved in water and by maintaining the temperature at about 32 F.

Liquid Oxygen Explosives

Pulverized charcoal saturated with liquefied oxygen is one of the most powerful explosives known. It finds considerable use in the mining industry and other places where it is practicable to install liquid air machines for the manufacture of the liquid oxygen. A liquid air machine is generally nothing more or less than an air-cycle refrigeration machine, operating on the Linde principle where the compressed cooled air is allowed to expand through a throttling valve, cooling itself in the process. This cooled air is then recompressed and re-expanded until the temperature drops below the critical point and the air liquefies. This liquefied air is then taken into a continuous distilling column where it is separated by fractional distillation into gaseous nitrogen and liquid oxygen, the gaseous nitrogen being discarded and the liquid oxygen being caught in vacuum-walled containers. It is possible to keep liquid oxygen in such vacuum-walled containers for as long a time as 24 hr, and it is transported in these containers to the mine or other location where it is to be used. There it is poured into cartridges containing pulverized charcoal and then ignited by a suitable fuse.

Small Arms Loading Plants

In addition to the usual commercial type of refrigerator used in cafeterias and office buildings in industrial plants, **air conditioning units** are needed in small arms loading plants. These are used particularly in connection with air-wash systems in tracer charging, primer charging, and incendiary charging operations. It is customary to have these units control both humidity and temperature, using deep well water for washing processes, cooling the air down to 45 F and then reheating to maintain a relative humidity in the neighborhood of 50 to 55 percent. The rooms in which the operations take place are usually maintained at approximately 70 F. In many plants of this sort, the tool gaging laboratories are also maintained at constant temperature and humidity to insure satisfactory tool measuring conditions.

Pyrotechnics Industries

Refrigeration is used in conjunction with air conditioning in the pyrotechnics industry for several purposes. The first of these is in order to control the oxidation rate in the drying of linseed-oil-coated magnesium. It is also used in controlling the moisture content of the air where hygroscopic materials are handled. Temperature control is also necessary in operations where volatile solvents or other volatile materials are exposed to contact with air.

Certain kinds of **smoke signals** contain such chemicals as ammonium perchlorate, hexachloroethane, ammonium chloride, and powdered zinc. If this mixture comes into contact with moist air, a chemical reaction takes place and it bursts into flame. It is necessary, therefore, to have very **careful control** of both **temperature and humidity** in handling this particular mixture. This is usually done by means of dehumidification of the air used in the rooms where the material is blended, weighed, and pressed. By maintaining the temperature at a low level, the evaporation of hexachloroethane is also reduced.

Many other similar types of pyrotechnic

mixtures must be treated in the same way on account of the ease with which the compositions react with any moisture in the air.

Another use of refrigeration, which is quite unusual, is in connection with loading sensitive primer mixtures into primer caps. Most of these mixtures are loaded wet, containing sufficient moisture so that they are safe to handle. After having been loaded into the primer cups, the moisture is then removed in a suitable drying operation. During the loading of the cups, however, it is necessary to keep the moisture in the primer mixture from evaporating, and this is done by maintaining the mixture at a low temperature to reduce the vapor pressure of its water. In the plant, this is accomplished by keeping the wet primer mixture in a small well-refrigerated closet which is part of the bench or table where the loading operation takes place.

The writers of this chapter have been handicapped by the necessity of withholding much statistical information because of war restrictions. It is hoped that enough has been given to demonstrate that the field is a large and varied one. Refrigeration is required at many temperature levels between +50 F and −360 F, thus affording fields in which single-stage compression, two-stage compression, barometric or steam jet units, absorption and adsorption systems all find application. Sizes vary as well from one-ton to several hundred tons capacity.

If you searched this chapter for something which was not found in it, please let the editors know.

57. PETROLEUM AND PETRO-CHEMICAL

Introduction

IT IS usually accepted that the birth of the petroleum industry in the United States was marked by the drilling of the Drake Well at Titusville, Pa., in 1859. In 1860, the first petroleum refinery was built in Titusville, for the production of illuminating oil. Some petroleum lubricating oils were made but were not too satisfactory, because it was then impossible to continuously remove wax from the oil, there being no means of refrigeration available. Natural refrigeration was not year-around.

Prior to the availability of our present-day lubricants, animal fats and vegetable oils were the recognized lubricants. These, however, were unsatisfactory, because they were too readily oxidizable.

Pontifex absorption-type refrigeration machines had been used in England and Scotland for paraffin-wax plants. Approximately in 1889, an installation of this type was made in an American refinery under American license which permitted year-around wax separation by cold-settling. At approximately the same time, reciprocating compressors were made available for this purpose, but these were huge, slow-speed units requiring special motors, which resulted in a high capital investment. Furthermore, lubrication of the compressors and elimination of oil from the refrigerant charge were a problem. Cold-settling had its limitations, such as low yield and pour test.

The demand for lower-pour-test oil with heavier body, which was selling at a premium, led to the development, in 1920, of the *centrifugal method of dewaxing* for the more viscous lubricating-oil fractions, from which the amorphous wax was first removed by cold-settling. This process required refrigerant temperatures of -50 F, which were not practical with absorption machines. Reciprocating booster-compressors were installed ahead of absorption machines in some installations, but, in others, complete compression equipment was used.

With the development of a suitable compressor valve and with corresponding shorter-stroke and higher-speed compressors, rearrangement of refrigeration cycles to suit existing lubricants, availability of direct-connected drivers of both the electrical and engine type, lower power costs, and better over-all performance, the compression cycle automatically superseded absorption systems for new installations.

The preceding information refers particularly to removal of the amorphous wax which is found in the more viscous lube stocks. However, the lighter lube fractions of crude, which have lower boiling ranges and are less viscous, commonly designated as wax distillates, can easily be filtered. Wax was separated from wax-distillate stock by means of pressing or filtering through multiplate filter presses fitted with canvas blankets, the charge stock having been chilled by means of refrigeration. After 1903, when scraper conveyors were put into double-pipe chilling machines, the wax distillate could be chilled continuously to the desired filtering temperature, and this feature brought about many changes in the method of removing the wax from the distillate. There were no further changes in dewaxing methods until the introduction of MEK in 1927. Today, as in recent years, refineries no longer have one or two major products, such as in earlier years, when lube oil was the prime product. The trend is toward producing not only the

J. Charls, Jr., Author Chapter 57. Born 7/25/14 in St. Bernard, Ohio. Educated at Canisius College, Buffalo, N.Y., BS, 1937. Formerly Application Engineer, Compressor Division, Buffalo Works, Worthington Pump and Machinery Corp., 1937–45.

Member, Engrg. Society of Buffalo, Inc., 1944; Amer. Petroleum Institute.

At present, Sales Engineer, Refinery Section, Worthington Pump and Machinery Corp., Harrison, N.J.

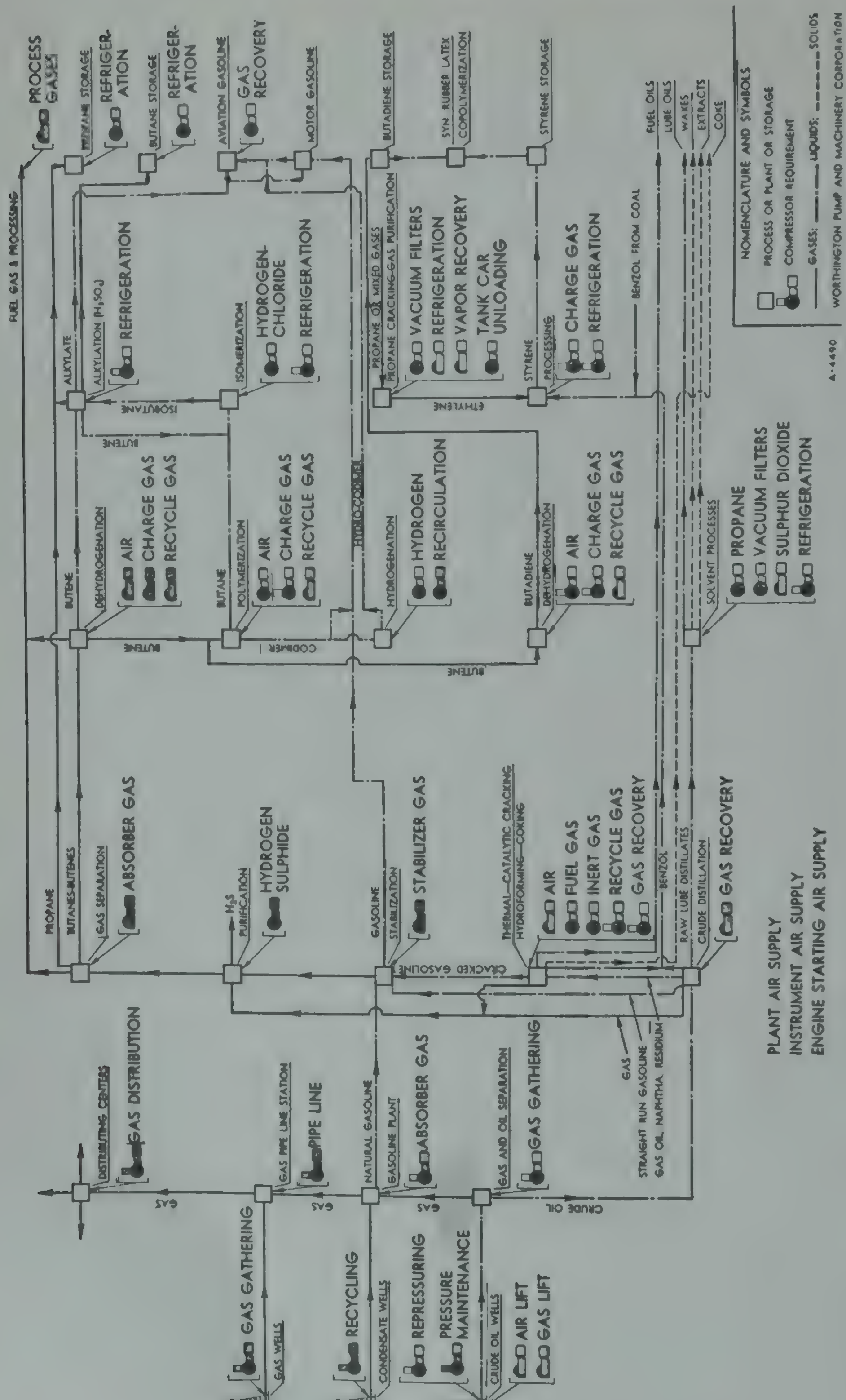

Fig. 1. Compressors and Refrigeration in Refinery Processes.

sual lubricating oil and fuels commonly lassified as petroleum products but also etro-chemical products, such as synthetic rganic chemicals, alcohols, ammonia, hloroform, phthalic anhydride, etc.

Compressor Equipment

As the various refinery products increased, the need for refrigeration at both low- and high-temperature levels also increased. Ammonia was the principal refrigerant, but, later, when hydrocarbons became available at plant site, they gradually replaced other refrigerants. Reciprocating compressors had proved successful in the compression of hydrocarbons in other plant processes. Therefore, the normal reaction was to use hydrocarbons as refrigerants in order to eliminate the necessity of purchasing a refrigerant from an outside source. Depending on temperature levels, such hydrocarbons as butane, isobutane, propane, and propylene were substituted for ammonia. Typical compressor requirements for refrigeration in refinery processes are illustrated in **Fig. 1**.

In view of the increasing demand for hydrocarbon refrigerants and lower temperatures for synthesis, various manufacturers developed centrifugal compressors for hydrocarbon service. It was found that the

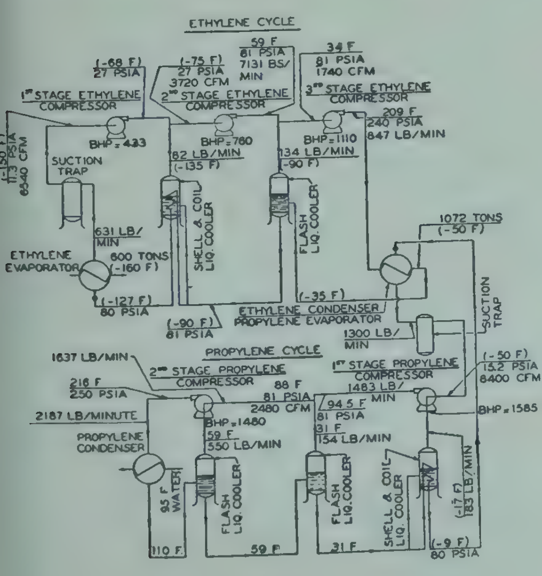

Fig. 2. Low Temperature Refinery Refrigeration Cycle.

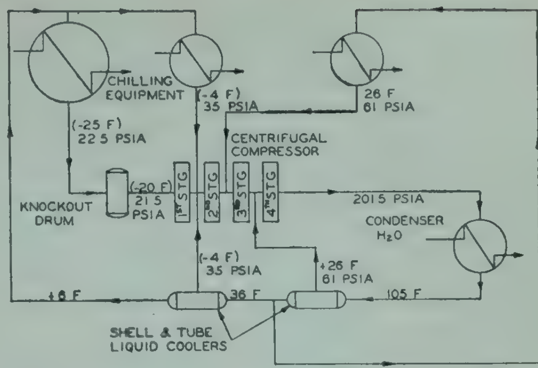

Fig. 3. Reciprocating System with Propane Refrigerant.

centrifugal compressor was ideal for refinery service because of:

1. Low first cost of compressors and drivers
2. Simplicity of piping
3. Minimum of foundations
4. Low maintenance cost
5. Simplicity of operation and control
6. High-service-reliability factor
7. Convertibility from one refrigerant to another.

In addition to the above, where lower temperatures were low and a cascade system was required, there was no longer the problem of selecting an oil for lubricating the compressors at their operating temperature and of preventing the same oil congealing in low-temperature evaporators which would decrease the effective cooling surface. **Fig. 2** is a flow diagram for a cascade system.

For normal present-day dewaxing conditions and for an evaporating temperature of −25 F and a condensing temperature of 100 F, it is the usual practice to install two-stage reciprocating compressors to carry the refrigeration load, as these conditions are ideal for such compressors. For similar conditions, a four- or five-stage centrifugal compressor would be used.

The centrifugal compressor offers greater flexibility than the reciprocating, because of its greater number of stages. In the case of the centrifugal, liquid-cooling or subcooling between stages is usually done in a minimum of two stages, as compared to the maximum of one stage in the reciprocating compressor, determined by the fact that

only one reduction in pressure from condensing to interstage, is possible. Furthermore, the additional stages permit injection of high-level loads at more points, eliminating the necessity of throttling from one high pressure to a much lower pressure, with consequent decrease in horsepower. **Figures 3** and **4** illustrate, respectively a flow diagram for reciprocating and a flow diagram for centrifugal system for the same operating conditions.

There are two main types of centrifugal-compressor designs, the diffuser and volute. Typical of the compressors installed in present-day refineries for hydrocarbon-refrigeration service are the following illustrations. **Figure 5** shows cross-section of a four-stage centrifugal propylene compressor with three nozzles in the upper part of the casing. The two end nozzles are suction and discharge openings, and the intermediate nozzle is for interstage flashing to obtain liquid subcooling.

Inherently, the centrifugal compressor is a large-volume machine. For capacities lower than 1,500 to 1,700 cfm at suction, the over-all efficiency is low, the advantage therefore being on the side of reciprocating equipment. **Figure 6** illustrates a turbine-driven installation in a large Gulf coast refinery, on lube-oil dewaxing.

Temperature levels, duty, and plant conditions will dictate whether it is more economical to install a reciprocating- or centrifugal-refrigeration system.

Chilling Equipment

In the majority of dewaxing processes, including those used in the industry at first and in modern present-day plants, double-pipe chilling machines and exchangers with spring-loaded scrapers provided a means of chilling lube stocks continuously without the disadvantage of wax congealing to the inner chilling surface decreasing effective refrigerant surface. The exchangers permitted the recovery of refrigeration from dewaxed filtrate, so that design-refrigeration-capacity requirements decreased, resulting in a corresponding lower installed and operating cost.

The earlier double pipes, which actually were exchangers, did not always utilize direct-expansion ammonia as their cooling medium, but, instead, cold refrigerated brine was circulated in the annular space between the 6″ and 8″ pipes. Consequently, refrigerant temperatures had to be lower to compensate for the temperature difference between refrigerant, brine, and dewaxing-oil temperatures.

With the advent of continuous dewaxing using solvents, chilling-machine designs were altered, until the inclined chilling machine was introduced. Heretofore, the horizontal chilling machine was suitable for low tonnages, so that installations were necessarily large-area. As a result of the availability of the inclined chilling machine, transfer rates increased to a point

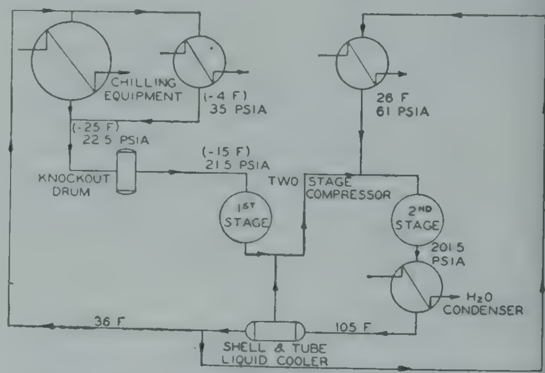

Fig. 4. Centrifugal System with Propane Refrigerant.

where the equivalent surface of the horizontal unit was used for plant flows fifty to one hundred per cent greater. The inclined chilling machine was suitable for either ammonia or hydrocarbon refrigerants, inasmuch as the elevated gas-return end readily permitted separation of liquid and gas without carryover of liquid to the refrigeration compressor.

A typical chiller-installation in the refinery is illustrated in **Fig. 7.** An exchanger is similar in construction to the chiller illustrated.

Scope of Application

It is the intention in this chapter to acquaint the individual with the diversified refrigeration applications in the petroleum and petro-chemical industry. It is practically impossible to cover each and every process in these fields with complete specific details. By showing the general past

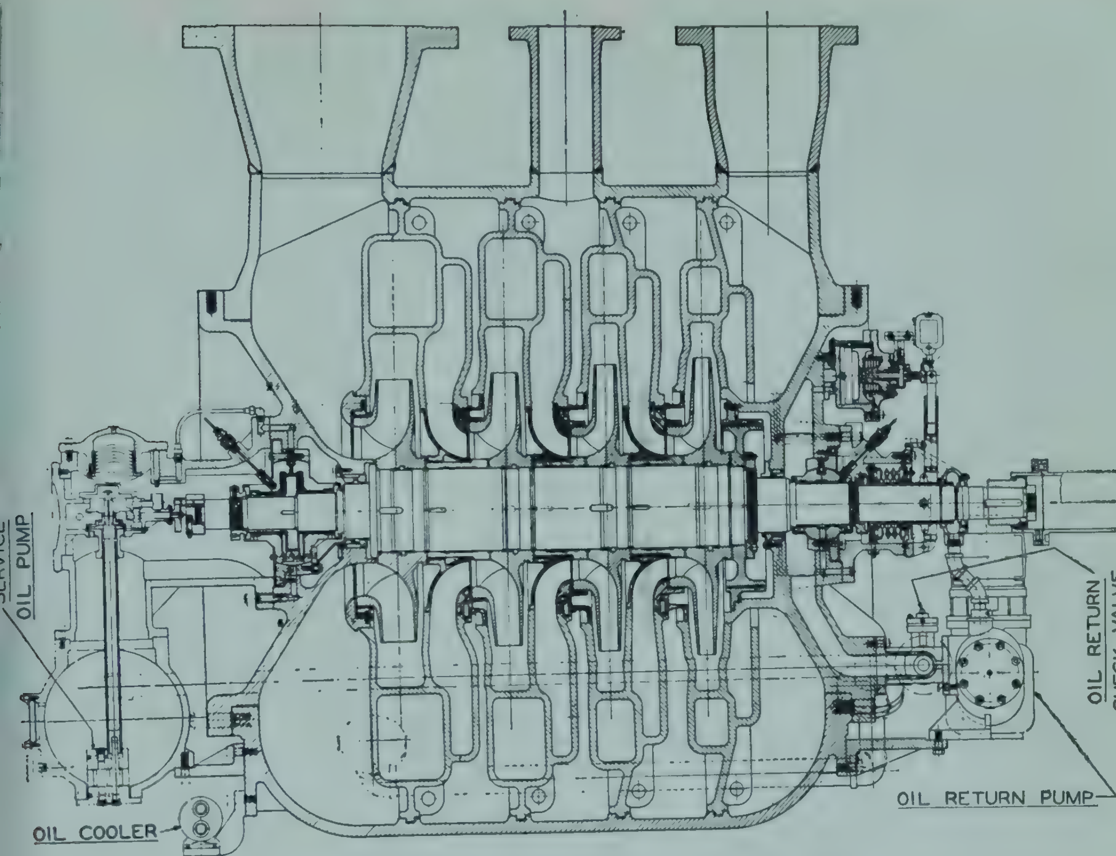

Fig. 5. Four Stage Centrifugal Propylene Compressor.

and present trend of the industries with relation to refrigeration, it is hoped the application of refrigeration to similar and modified process flows will be readily comprehended. Some processes differ only in temperature and pressure levels, refrigerants, or type of compressor equipment; others in solvents and carriers.

The last war showed the necessity for synthetics of all types. The result of continuous research by the petroleum and petro-chemical industry has been to make available new sources of raw material, as, for example, chemicals for dyes, rubber, which heretofore were purchased from other countries. The development program for substitutes led to many new by-products, with corresponding increasing demand for refrigeration. The light hydrocarbons which, in the past, were piped to a flare or used for furnace fuel, are now recovered and find their way into many synthetics.

Chemically, petroleum consists mainly of carbon hydrogen compounds, paraffins, napthenes, and aromatics. Asphaltic material resulting from partial oxidation of hydrocarbons is also present. The paraffins exist as waxes at normal temperature ranges and are removed from the various lube oils by chilling and filtration after distillation. Crudes are classified into three main types: Paraffin, naphthene, and mixed base.

Separation of the crude into various constituents or fractions is accomplished by distillation. In this step, the lower-boiling components are separated from the lubricating-oil fractions and processed for specialized fuels, cracking stocks, solvent naphthas, etc. It is estimated that there are over 5,000 essential products that are derived from the initial crude charge.

Solvent Dewaxing and Refining

The first method of wax separation employing refrigeration was cold-settling. In this process, the lube stock was mixed with

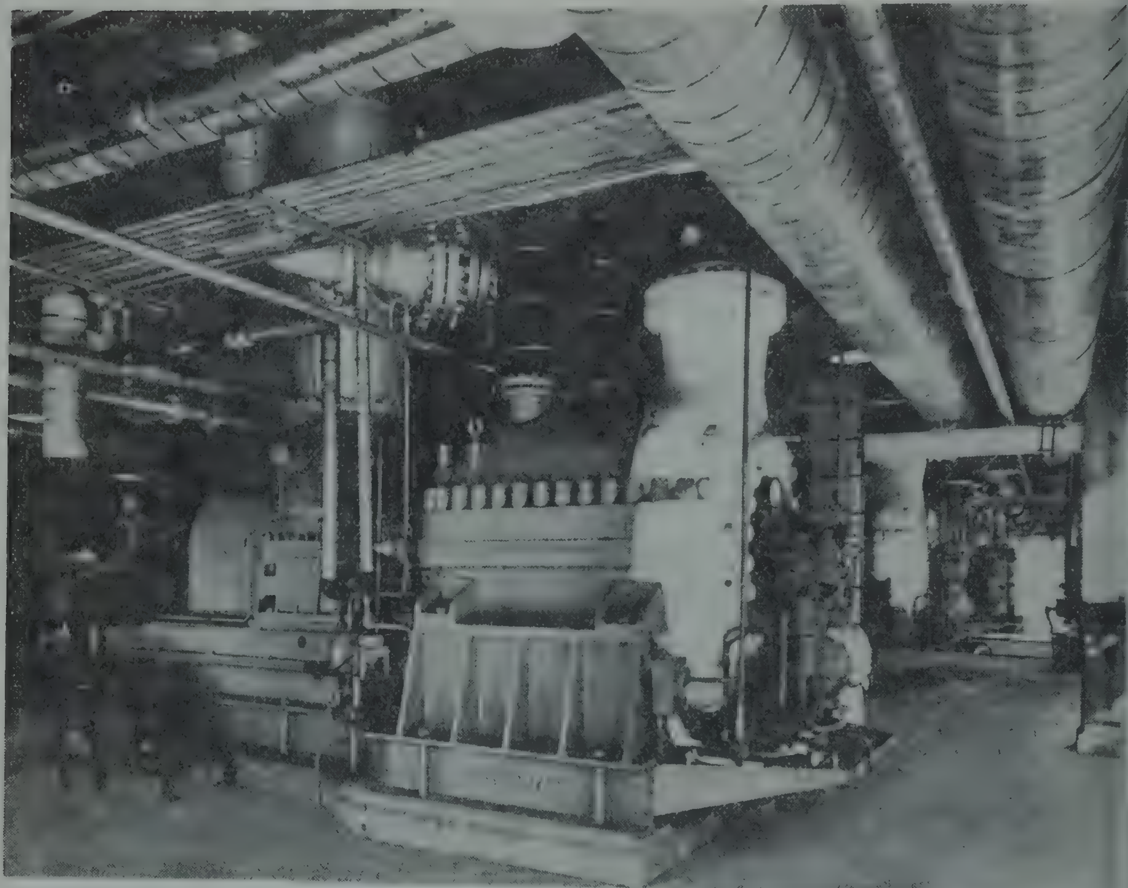

Fig. 6. Centrifugal Propane Compressor.

naphtha, chilled in insulated tanks, and allowed to settle for several days. The upper layer in the chilling tank, partially dewaxed stock, was decanted above the level of a cloudy stock which was the next layer in the tank. This cloudy stock was further processed and dewaxed after the petrolatum, or bottom layer in the chilling tank, had been removed by pumping. This method of dewaxing pertained to amorphous-type wax found in the more viscous oil stocks which was not easily removed in filter presses or *pressing plants*.

In *pressing plants*, the lower-boiling-range less viscous crudes, called wax distillates, were chilled, after distillation, to a temperature 5 or 10° below the desired pour point of the finished neutral (dewaxed and processed wax distillate used as blending stock in the production of a large percentage of motor oils) in double-pipe chillers filtered under pressure in multiplate presses where the wax was retained in the filter by canvas-blanket assemblies usually separated by one-half-inch steel rings which acted as reservoirs for collecting wax. The filter presses were installed in insulated rooms or vaults such as illustrated in **Fig. 8** and not individually insulated, because of the necessity of dumping the presses or removing the cake wax from the individual plates every eighteen to twenty-four hours. Another reason for using insulated vaults was to eliminate temperature increase of the dewaxed oil which drains from the blanket assemblies during the filtering operation.

Single pressing is performed for 20 F pour point, whereas double pressing is required for 0 F pour test.

It was customary to perform the first pressing operation round +40 F, whereas the second pressing was conducted at approximately −10 F. As a general rule, the

slack wax left in the press was considered to be 30% by volume of the initial wax distillate for the Pennsylvania field. For the Mid-Continent and Gulf Coast field, this was taken as 18%. Twenty-five percent of the wax was assumed to be removed in the first pressing operation and 75% in the second operation.

The refrigeration requirements for the chillers and press vaults averaged one ton of refrigeration for each ten barrels of wax distillate processed. This was reduced approximately 15 to 20% if refrigeration was recovered by precooling the wax distillate with the filtered oil during final pressing.

After the filter press was dumped, deoiling of the wax was accomplished by a *sweating* operation after the wax had been chilled to a solid mass.

Wax-sweating to remove oil entrained in wax, operated on the theory that wax in a solid state has many voids which trap oil, but, as the temperature of the wax is increased, the voids expand, allowing draining of the oil from the sweating pans.

The sweating pans are usually shallow-steel-construction, 50 ft long, 10 ft wide, triangularly sloped toward their bottom centers, having screen mesh or perforated plates located approximately at two thirds of the depth of the pan. Over the screen or plate is placed a coil, which is used for cooling the wax. Banks of these pans are placed in an insulated room.

Water is pumped into the pans until it covers the perforated plates or screens, and the hot wax is pumped into the pans. Cold water is circulated through the coils, and the wax is chilled below its melting point, so that it solidifies into a cake. The insulated room is then tightly closed, water withdrawn from the pans, and the temperature of the room increased by steam coils along the walls of the room. The oil sweats out of the wax as the wax temperature increases, drains through the screens to storage through pipes in the bottom center of the pans. The process continues until all of the oil is sweated from the wax.

Replacing or superseding *cold-settling*, a continuous method of separating precipitated amorphous wax from a naphtha solution was adopted. This method was called *centrifuge-dewaxing with naphtha* and is not to be confused with the *Bari-Sol process* of dewaxing. In *centrifuge-dewaxing*, a light solvent is used which permits wax to be removed through the aid of a carrier at the

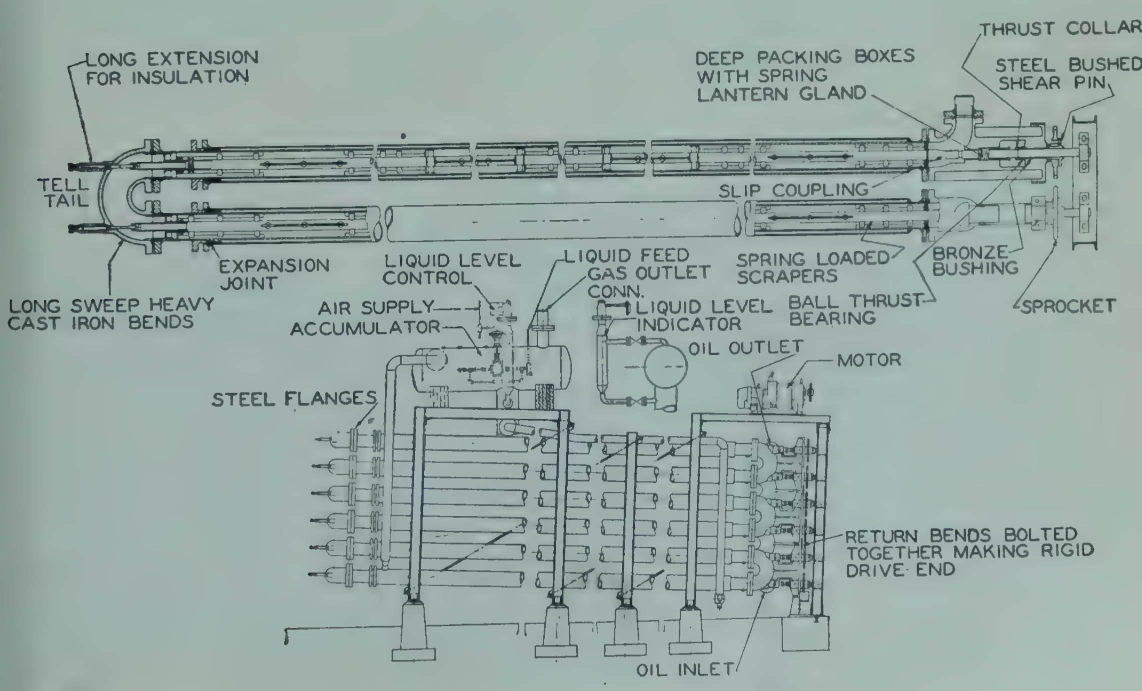

Fig. 7. Inclined Direct Expansion Chilling Machine.

outer surface of the centrifuge rotor, whereas, in the *Bari-Sol process,* a heavy solvent is used which causes removal of wax from the center of the centrifugal rotor by mechanical means and does not require a carrier, so that it is possible to dewax all types of lube stocks.

In *centrifuge-dewaxing,* the stock to be dewaxed was blended with naphtha initially chilled by exchange in chilling towers with cold dewaxed-oil dilution and finally chilled by direct-expansion ammonia chilling towers to the temperature required for centrifuging. The direct-expansion ammonia chilling towers were added to this cycle and cold dewaxed oil substituted for refrigerated brine after the demand for lower-pour-point oil prevented the use of brine because of the 30 to 40° spread required between centrifuging temperature and pour point of the dewaxed oil. Although this system was essentially a batch operation, wherein multiple chilling tanks are chilled over a 48-hr period, the system could be made continuous. A typical flow is shown in **Fig. 9.**

The *Bari-Sol centrifugal dewaxing process* employs solvents which are heavier than the oil to be dewaxed or the wax to be separated from the oil. Normally, the solvent is a mixture of ethylene dichloride and benzol. This process was developed at about the same time as the naphtha process, but since its solvent was not commercially available at a reasonable price, and since pressing for wax distillate was satisfactory, the *centrifuging* with *naphtha* taking care of amorphous stocks, this process was temporarily shelved, until a heavy solvent became commercially available.

A typical plant-flow description is as follows. The lubricating stock, solvent, and recovered oil dilution from secondary centrifuging are blended in the blending and heating tank initially cooled by series flow through double-pipe scraped-surface exchanger countercurrent to cold dewaxed oil and solvent. Final chilling is obtained in direct-expansion, scraped-surface, inclined chilling machines, where the refrigerant is normally ammonia. After final chilling, the mixture is separated in primary centrifuges into dilute dewaxed oil and waxy-oil solution. The dilute dewaxed oil is discharged from the primary centrifuges to a run tank, from which it is pumped to a solvent-recovery unit after passing through the annular space of the double-pipe exchangers for initial chilling of the charge-stock mix for recovery of refrigeration.

The waxy-stream discharge from the primary centrifuge is mixed with cold solvent which has been chilled by exchange with recovered oil dilution from the secondary centrifuges and refrigeration in shell-and-tube coolers. After the mixing with chilled

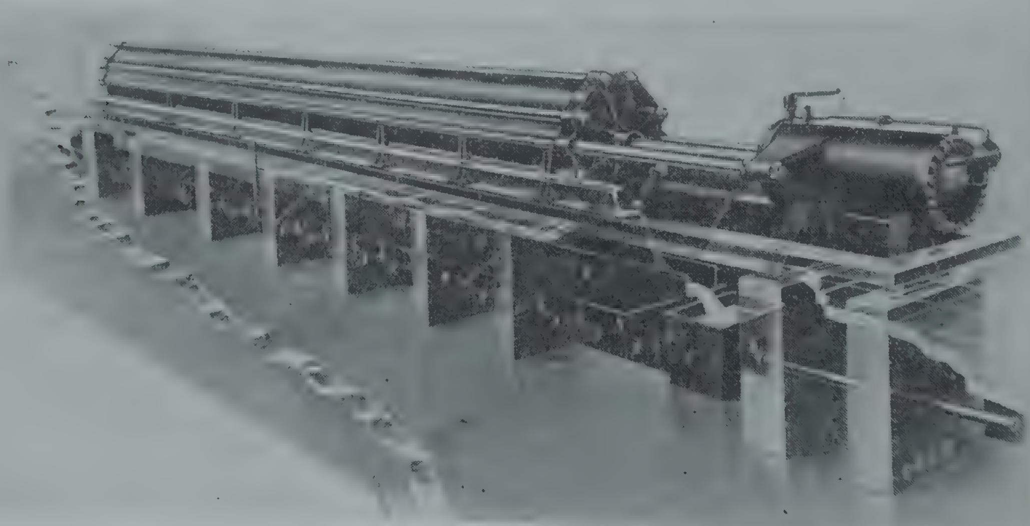

Fig. 8. Filter Press Installed in Insulated Room.

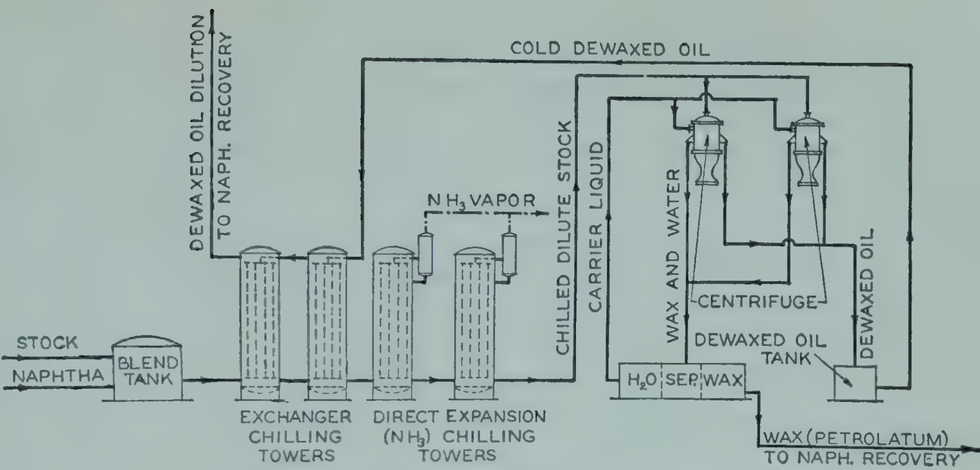

Fig. 9. Centrifuge (Naphtha) Dewaxing Process.

solvent, the waxy-stream stock is further processed in the secondary centrifuges for the separation of petrolatum and dilute oil. The petrolatum-dilution discharge is pumped to a solvent-recovery unit for further processing of petrolatum. The recovered oil dilution is pumped through the shell-and-tube exchangers for cooling of solvent and then to the blending tank, where it is mixed with the initial charge of oil stock and solvent as described in the beginning of the section on plant flow. A simplified flow diagram is illustrated in **Fig. 10.**

Solvent Dewaxing

In 1927, the Solvent Dewaxing Process was developed at the Lawrenceville, Illinois, refinery of the Indian Refining Company, and, since that time, the use of this process has expanded in the United States and Europe. This process is frequently called MEK Benzol or Acetone Benzol process. The licensor of this process is the Texaco Development Corporation. Today, as in the past fifteen years, this process is generally accepted as the one to use for dewaxing lubricating-oil stocks. If present installations and contracts for additional

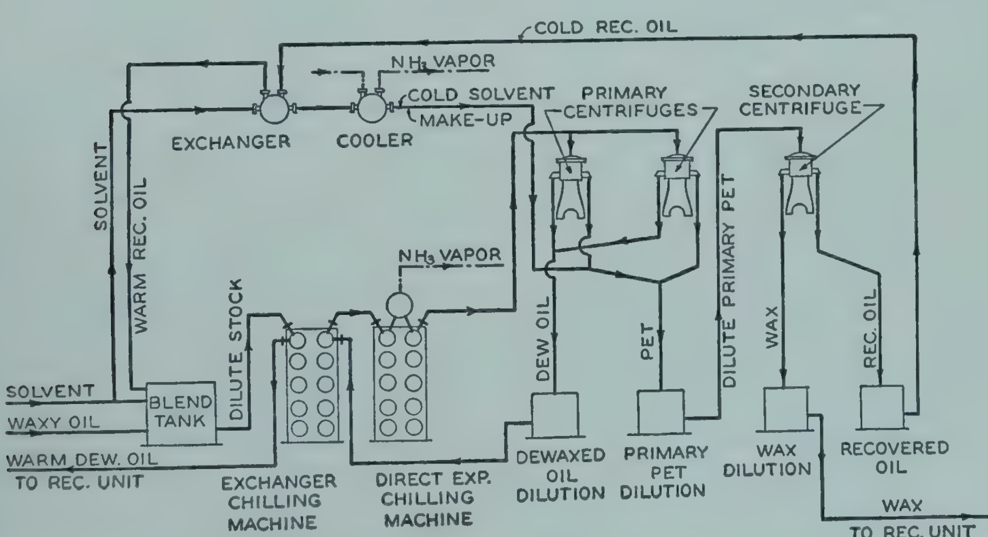

Fig. 10. Bari-Sol Dewaxing Process.

units are taken into consideration, it is estimated that soon the daily charging capacity will be 200,000 barrels per day.

The solvent mixture used in this cycle possesses the characteristics of the ideal solvent, which are:

1. At a temperature of 100 F to 150 F, the lube stocks must be completely miscible with the solvent, whereas, at low temperatures of about 0 F, solvent action is exerted on the liquid hydrocarbons with little or no solvent action on the waxy paraffin hydrocarbons present.
2. When a solution of lube stock and solvent is chilled to a filtering temperature of about −10 F, filtered, and solvent removed from the products, the oil should have a pour test of approximately 0 F.
3. The solvent must be cheap, noncorrosive, and readily obtainable.
4. The character of the liquid must be such that the wax contained in the charge stock will be crystallized into a form which can readily be filtered.

In various lube-oil plants, when the solvent is a mixture of methyl-ethyl-ketone, benzol, and toluol, a high yield of wax-free oils with low pour points has been obtained. Proper solvent selection and dewaxing conditions insure as nearly as possible complete separation of wax-free oil from oil-free wax.

Normally, each of the solvents in the above mixture serves as follows: Benzol retains oil in complete solution at dewaxing temperature; methyl-ethyl-ketone acts as an antisolvent, preventing the wax from remaining in solution at the dewaxing temperature; the action of toluol is similar to that of benzol but has the added advantage over benzol of preventing benzol crystals from forming at dewaxing temperature.

A typical flow diagram for the Solvent Dewaxing Process is **Fig. 11.** The waxy oil-solvent charge mixture, consisting of oil stock to be dewaxed and solvent, is first chilled by water to approximately 110 F, then passed through 6″ pipes of double-pipe exchanger fitted with spring-loaded scrapers, where it is further cooled by means of exchange with cold dewaxed filtrate in the annular space between the 6″- and 8″-pipe sections. Final chilling is obtained by passing the charge stock through the 6″ pipes of direct-expansion, inclined chilling machines fitted with spring-loaded scrapers, either ammonia or a hydrocarbon being used as the refrigerant. After being chilled to the final temperature, the charge oil and solvent mixture enters the filter-feed tank, whence it is fed by gravity flow to rotary-type vacuum filters, where the wax is removed from the chilled stock and further processed in a wax-recovery system. The wax-free filtrate solution is collected in the main filtrate receiver and is pumped through the annular space of the exchangers to evaporators for the recovery of solvent and further finishing of the oil.

Dehumidification is accomplished by

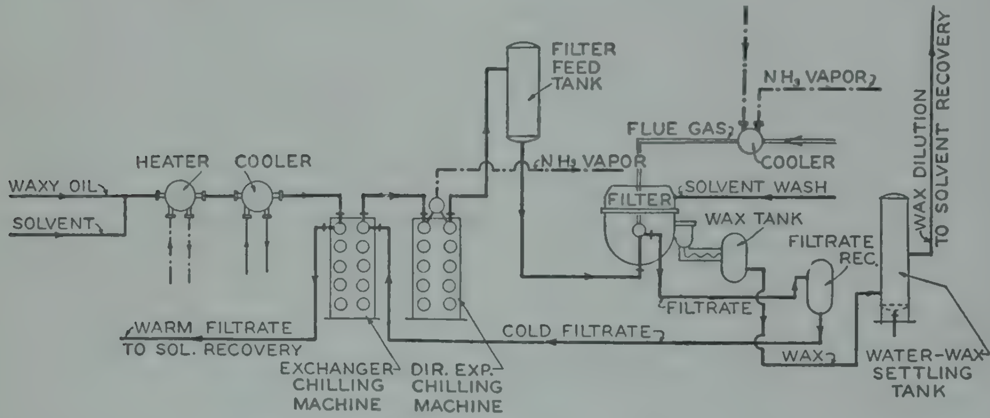

Fig. 11. Solvent (M.E.K.) Dewaxing Process.

ystallizing the water and removing it in ne wax-mix surge tank.

The above process is very flexible, accomplishes almost complete separation of l from wax, permits production of various ypes of waxes from soft waxes to microystalline, has the inherent quality of ninimizing fire hazard and solvent loss by ne use of a closed-type flue-gas system. By neans of varying solvent and charge-stock atios and recent innovations, refrigeration equirements have been decreased, and the irect-expansion, inclined chilling machine esigns have been improved to such an exent that plant-design conditions are coninually being exceeded.

Except in rare instances, where state or ocal plant codes dictate otherwise, standrd materials of construction are acceptale, there being less demand for special maerials such as nickel-steel.

The adaptability of either centrifugal or eciprocating refrigeration compressors, ydrocarbons being used in the former and mmonia or hydrocarbon refrigerants in he latter, has further added to the flexibilty of these plants.

This process has not only been accepted or lube-oil stocks but also in the chemical ield for fatty-acid crystallization to proluce stearic, oleic, and linoleic acids.

Propane De-Asphalting and Propane Dewaxing

Propane de-asphalting and propane dewaxing use propane in the first process, as the solvent for separating asphalt and other undesirables from reduced crudes and, in the latter, for separation of wax from crudes by solvent action and as a refrigerant.

The M. W. Kellogg Company has been appointed licensing agent for the processes, which licenses are granted under the patents and patent rights of Standard Oil Company (New Jersey), Union Oil Company of California, Standard Oil Company (Indiana), and the M. W. Kellogg Company.

The dewaxing cycle consists of the following: A mixture of oil and propane are warmed to insure the solution of all of the wax in the charge stock, initially cooled by exchange with dewaxed solution and water, chilled in a vessel to −40 F by propane in the mix evaporating at a maximum fixed rate, which fixed-rate control is obtained by means of unloading, speed control, or a combination of both on reciprocating compressors. The wax is separated from the oil in continuous rotary filters. The wax crystals are washed with cold propane in the filters to remove oil adhering to the crystals. The resultant wax-propane mix is pumped to propane evaporators, where most of the propane is vaporized by steam, and converted to liquid in water-cooled condensers. The recovered propane is mixed with the initial wax-bearing oil-charge stock at the beginning of the cycle. Propane is also partially removed from the dewaxed-oil solution in the same manner. Final removal of propane from wax and dewaxed-oil solution is accomplished in strippers. The propane vapor from the final stripping operation is combined with the propane vapor coming from the chiller tank, compressed by reciprocating compressors, and condensed in water-cooled refrigerant condensers.

Compressor installations are usually of the two-stage type. At the beginning of the dewaxing cycle, where the compressor suction pressure is almost equal to condensing pressure, part of the second-stage-compressor-cylinder effective capacity handles the propane gas resulting from evaporation, whereas, when the suction pressure or tank pressure decreases to a point where the entire capacity of the high-pressure cylinder is required to remove the propane vapors resulting from cooling the waxy-oil charge stock, the entire capacity of the second-stage compressor cylinder is used. Likewise, as the suction pressure decreases to a point where two-stage operation is required to eliminate the propane gas resulting from evaporation, the first-stage compressor is partly loaded. After the change from single-stage-compressor operation to two-stage operation, the compressor pulls the suction pressure down to that corresponding to −40 F or the required condition for the particular pour point of oil being dewaxed. Lowering of pressure in chilling tank permits more flashing of propane, which cools the charge-oil stock. The pro-

pane, after being condensed, is subcooled by means of exchange with the cold dewaxed oil and wax solution and pumped to a cold propane tank which is the source of supply of cold propane for washing the filter cake in the rotary filter in order to remove any oil adhering to the wax crystals.

The advantages of propane dewaxing are:

1. Low solvent cost
2. Solvent used as refrigerant and easily recovered
3. Low pour test dewaxed oil
4. Wax yield with low oil content
5. Possibility of combining propane deasphalting and acid treatment with the dewaxing step.

Solvent Refining

Before the dewaxing step, hydrocarbon mixtures are separated on the basis of their solubilities, in order to obtain their desirable properties. Earlier in the chapter, mention was made of the paraffinic, naphthenic and aromatic compounds found in crude. By the use of solvents, these compounds can be separated and individually processed.

The *Duo-Sol Process,* licensed by Max B. Miller & Co., Inc., New York, uses two solvents. Propane is the paraffinic solvent; Selecto, a blend of phenol and Cresol, is the naphthenic solvent.

The *Furfural Refining Process,* licensed by the Texaco Development Corporation of New York, and the *Phenol Extraction Process,* licensed by the M. W. Kellogg Company of New York, use furfural and phenol, respectively, for removing the low-viscosity-index, poor-color, and unstable materials from the raw lubes. Plants must be designed to handle either furfural or phenol, as the two solvents have different chemical and physical characteristics.

The *Propane De-Asphalting Process,* for which the M. W. Kellogg Company is the licensing agent, uses propane as a solvent for separating asphalt, color bodies, and other undesirables from reduced crudes. This process consists mainly in charging heated reduced crude into the upper portion of a de-asphalting tower and propane into the lower portion of the tower. The propane flows upward in the tower countercurrent to the descending asphalt. The propane-oil solution is removed from the top of the tower, and propane-asphalt solution from the bottom of the tower. Propane is removed from the two separate streams by steaming and flashing, is compressed and condensed by water.

The foregoing processes for solvent refining to separate the paraffinic compounds from the naphthenic and aromatic, accomplish their purpose without refrigeration. However, the following do employ refrigeration.

The *Nitrobenzene Extraction Process,* developed and used by the Atlantic Refining Company, Philadelphia, Pa., as its name denotes, employs nitrobenzene for separating the desirable and undesirable constituents. The paraffinic compounds are almost insoluble in this solvent, whereas the aromatic, naphthenic, and asphaltic are highly soluble.

The charge oil is chilled initially by a water-cooled chiller, mixed with extract from second-stage extractor, and finally chilled by a brine chiller. The chilled charge-stock mixture enters the five-stage-extractor mixer-settler tank and flows countercurrent to chilled nitrobenzene, which enters the extractors at the fifth stage. The paraffinic naphtha solution is pumped from the fifth-stage extractor unit to solvent-recovery system, whereas the naphthenic, aromatic, and asphaltic nitrobenzene mixture leaves the first stage and is pumped to solvent-recovery system. Refrigeration is twice employed: once to chill the charge-stock mix, and again to chill nitrobenzene prior to its entrance into the fifth-stage extractor. Refrigerant temperatures are 30 to 40 F. A partial flow diagram of this process without its solvent-recovery system is shown in **Fig. 12.**

The *Edeleanu Process* for solvent refining of petroleum products was first used approximately in 1911. Plants designed and installed by the E. B. Badger & Sons Company, Boston, are used for the production of kerosene for improvement of quality, separation of aromatics from naphthas, improved Diesel fuel, transformer oils, aviation-gasoline blending stocks, solvents, and light lubricating oils. This solvent, liquid sulfur dioxide, depending on temperature

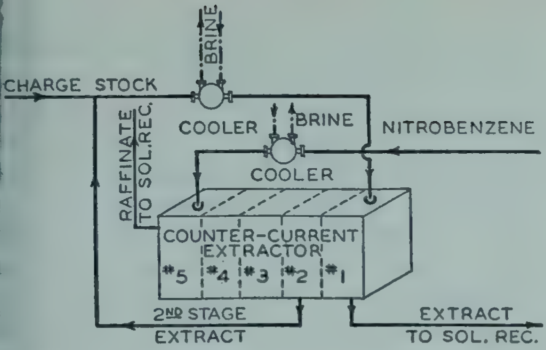

Fig. 12. Nitrobenzene Extraction Process.

conditions, has a tendency to low solubility for paraffinic hydrocarbons, to a small extent for naphthenic, to a large extent for aromatic hydrocarbons.

Liquid sulfur dioxide is the only solvent-refining process by which all fractions of mineral oils may be extracted. In addition, the solvent is employed as a refrigerant.

Sulfur dioxide mixed with benzol makes possible the processing of lube stocks. A simplified flow diagram is shown in **Fig. 13.** This diagram does not show the equipment for recovery of solvent dissolved in the refined oil or extract from extraction tower, refrigeration system, or dehydrating equipment.

The charge stock is filtered, cooled initially by exchange with cold solution from the extraction system, diluted with mix solvent, and finally cooled by refrigeration in the charge and sulfur dioxide cooler, through which the stock flows in coils immersed in solvent. Refrigeration is obtained by evaporation of the solvent. The stock-and-solvent-cooling tank is maintained near atmospheric pressure by two-stage compressors which remove gas resulting from evaporation of the liquid sulfur dioxide. This refrigerant gas is condensed in the type of two-stage-compression cycle normally employed for refrigerant plants with two-stage-compression equipment, except that there is no inter-cooling between stages. The solvent gas removed from the oil and extract under vacuum conditions is pressurized by a booster-compressor to the pressure corresponding to the two-stage initial suction pressure, and condensed in the same manner as is the other sulfur-dioxide gas resulting from cooling of the charge stock and solvent.

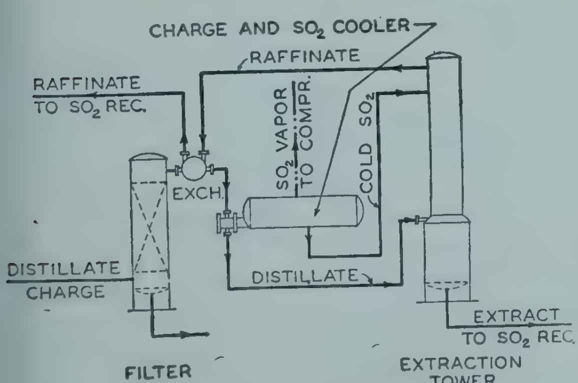

Fig. 13. Edeleanu (SO_2) Treating Unit.

Natural-Gasoline Production

At first, the prime purpose of natural-gasoline plants was the recovery of gasoline from casing-head gas. Because of new market conditions, the demand for butane, propane, and other hydrocarbons which had previously been wasted as plant fuel gas, increased.

The basic types of extraction systems are the *absorption* and the *compression systems.*

The *Absorption System* consisted in passing rich gas countercurrent to lean absorption oil in a bubble-plate tower. The incoming gas and lean oil were refrigerated, although, in earlier types of absorption systems, only the lean oil was cooled. Absorption properties depended upon temperatures, and it was found that, by controlled temperature selectivity, elimination of the heavier from the lighter gases could more readily be accomplished. **Fig. 14** shows a typical absorption natural-gasoline plant which does not use refrigeration for the wet gas.

In the *Compression System* for extraction, gas from wells is increased in pressure by compressors of the multistage type. Between compression stages and after, the gas is cooled by water so that the gasoline is condensed out of the gas. Later, refrigeration was added to the discharge gas coming from the final stage of compression, and the cooled gas was dehumidified by contact with glycol solution and further processed with cold reflux to condense the heavier hydrocarbons.

The necessity of removing the various undesirable hydrocarbons in order to obtain a stabilized or "weathered gasoline" of the proper volatility, forced many natural-gasoline-plant owners to install means of separation and recovery, so that they could take advantage of the market trend for the hydrocarbons not required for gasoline. It was therefore logical for the refineries to follow the same practice with gasoline derived from their cracking units.

In one gas plant, designed and constructed by E. B. Badger & Sons Company, of Boston, gas and gasoline from a catalytic cracking unit and catalytic treating unit are processed to produce such products as isopentane, pentane, butane, propane, aviation gasoline, and motor gasoline. In this process, the de-ethanizer-column reflux is refrigerated by propane in a kettle-type unit at a temperature of 40 to 50 F.

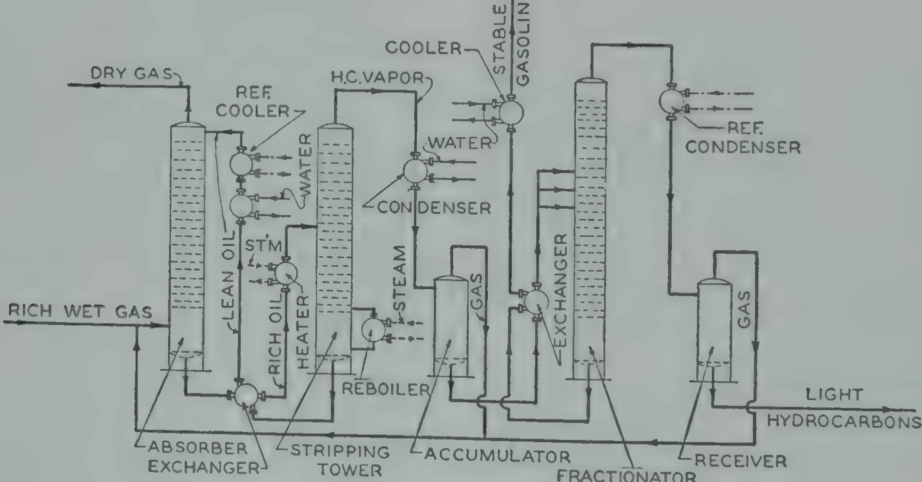

Fig. 14. Absorption Natural Gasoline Plant.

Isomerization and Alkylation

As a result of increased light-hydrocarbon recovery from natural-gasoline plants and resultant end products from cracking units, new uses were found for these products. Prior to the last world war, emphasis was placed on higher octane ratings for gasoline in order to obtain aviation fuel. Also, in the manufacture of synthetic rubber, butylenes became predominant. The demand for these recovered hydrocarbons increased tremendously. Alkylation units required butane derivatives for their charge stocks, in order to make aviation gasoline. To compensate for shortage of alkylation feed stocks, isomerization units converted normal butane into isobutane.

Isomerization is a reaction involving the rearrangement of the molecular structure of a hydrocarbon without changing its molecular weight but possibly altering its critical pressure and temperature, and its boiling point. The *Butane Isomerization* process, licensed by Shell Development Company, New York, passes normal butane vapors to parallel reactors containing basically aluminum-chloride catalyst in granular form. A catalyst promotor, dry HCl gas, is mixed with the butane vapors going to the reactors. Butanes are condensed by passage of the discharge from the reactors through a refrigerated cooler and condenser. Refrigeration is further utilized for the HCl stripper in a condenser supplying the reflux.

Alkylation

Alkylation consists in combining an isoparaffin such as isobutane with an olefin (butylene, proplyene, or amylene) to produce a higher-molecular-weight hydrocarbon of the branch-chain type, commonly called alkylate.

Various processes are used for alkylation, one of which uses sulfuric or hydrofluoric acid as the catalyst with different designs for contacting and separating the catalyst from the hydrocarbon mixture, depending on the catalyst used. Another process employs sulfuric acid as the catalyst.

For both sulfuric-acid-catalyst systems, the heat of reaction is removed by refrigeration.

Ethylene Production and Recovery

Of prime importance for organic-chemical manufacture is the petroleum-derived hydrocarbon ethylene. Ethylene is the basic chemical for ethylene glycol and ethylene oxide. Both of these chemicals find their way into unlimited chemical syntheses and products. For example, ethylene glycol is used in antifreeze and explosive manufacture, ethylene oxide in the production of detergents, acrylonitrile, and synthetic rubber.

Ethylene may be produced by pyrolysis of ethane, propane, or heavier hydrocarbons, or as a cracking-plant by-product. Various cycles have been designed and used for its production and recovery. Depending upon plant design, heat balance, utility balance, and other desired recoverables, all systems or only one will be economical and practical. It may be that a combination of different designs for recovery and purification would show the best payout.

One of the most widely used processes for ethylene production and recovery has been designed by Stone and Webster Engineering Corporation, Boston. Seventy-five percent of all the ethylene produced in this country is produced by means of this process, in which fresh feed, with recycled ethane and propanes, is charged to the pyrolysis furnace and heated to approximately 1,450 F. The resulting cracked-gas mixture is cooled to approximately 100 F after being water-quenched at the coil outlet below cracking temperature. By means of multistage compression, the cracked gas is compressed to approximately 600 psig and subcooled for initial dehumidification at nearly 65 F. Desiccant driers employing activated alumina or bauxite dry the gas to a dew point approaching −100 F.

In one large chemical plant, the gas is initially cooled at −35 F, finally cooled at −75 F, and then introduced into the demethanizer condenser, where a reflux temperature of −130 F to −140 F is provided by ethylene refrigeration in a run-back-type condenser. The bottoms are fed to an ethylene tower, where high-purity ethylene is recovered overhead in a condenser refrigerated with propylene, providing reflux at an approximate temperature of 0 to −25 F with refrigerant temperature of approximately −50 F. The bottoms from the ethylene tower are fed to an ethane column where ethane and propanes are removed and recycled to the cracking furnace.

The refrigeration system is cascade, propylene in the upper level taking care of drier-requirement precooling, ethylene, ethane, and propane condensing, and condensing the ethylene in the lower end of the cascade system.

The lowest temperature level in the propylene cycle is −50 F. The ethylene cycle provides refrigeration for the final cooling of cracked-gas stream and reflux in the demethanizer condenser with refrigerant at −160 F. The compression equipment consists of centrifugal compressors of the three- and four-stage volute design, as illustrated in the earlier part of the chapter. Means have not been provided to warm up the cold suction gas in the ethylene system by exchange with warm liquid refrigerant, as this is not required with centrifugal compressors from a lubrication standpoint. All initial suction temperatures approximate tower operating temperatures.

Plants for the production of *Ethylene by Pyrolysis* of ethane, propane, and propylene and direct recovery of ethylene from the raw charge gas have been designed and constructed by The Lummus Company, New York.

The most important tower in this process is the fractionating absorber, which makes the split between methane and ethylene. Charge gas, mixed with recycle gas from the pyrolysis tubular heaters, is compressed in three stages of compression and initially dried by water-cooling, refrigera-

tion, and desiccants to a dew point of approximately −40 F. The charge flows from the desiccant driers to the absorber, where the dried oil, containing essentially propane, propylene, ethane, and ethylene, is taken from the bottom and further processed in the de-ethanizer tower, from which the overhead flows to the ethylene fractionator for removal of ethylene. Methane and hydrogen are removed in the absorber. The bottoms from the de-ethanizer flow to the depropanizer tower, and the removed propane and propylene flow to the tubular heaters for cracking and recycle. The bottoms from the depropanizer tower pass to a rerun tower where aromatic materials are removed for absorber-lean-oil circulation to aid in the recovery of ethylene from the feed and removal of hydrogen and methane. Any heavy polymer forming in the aromatic distillate is eliminated in the rerun tower.

Ethane is removed in the ethylene fractionator and flows to the tubular heaters for cracking and mixing with the charge gas.

Refrigeration is employed in the absorber, de-ethanizer, ethylene fractionator, and for partial gas drying. Refrigerant-temperature levels range from approximately −40 to + 40 F, and the refrigerant is normally plant propane.

If you searched this chapter for something which was not found in it, please let the editors know.

58. REFRIGERATED PIPE LINES

ABOUT 50 years ago mechanical refrigeration for cold storage warehouses came into use, succeeding refrigeration for this industry by means of ice or of mixtures of ice and salt. The location of wholesale food establishments and commission houses in the vicinity of the warehouses in a few of the larger cities made possible the distribution of refrigeration by pipe lines from a central station at the warehouse. Originally this service was largely for the refrigeration of dairy products, fruits, vegetables, and meat and poultry, for short periods awaiting sale and distribution by the wholesaler. It also served retail markets and restaurants. These continue to be major uses of the pipe line business. Today, however, customers are supplied with refrigeration for air conditioning, drinking water systems and, to a limited extent, quick freezing of food products where feasible.

There are 30 or 40 public refrigerated pipe lines in the country, but most of them are comparatively small. Of the five major pipe lines which have all been operating for approximately 50 years, one is located in Boston, two in New York, one in St. Louis, and one in Los Angeles. These are all adjuncts to cold storage plants. All of these lines have been extended from time to time, but the development of the smaller commercial units has created a competitive situation.

GEORGE A. HORNE, Author Chapter 58. Born 9/29/77 in Plainfield, N.J. Educated at Lehigh University, BS, 1899. Formerly, Chemist, Thomas A. Edison Company, W. Orange, N.J., 1899–1900; Chief Chemist, Chemical Engr., B. T. Babbitt Soap and Glycerin Mfg. Co., Babbitt, N.J., 1900–10; Chief Engineer, Vice President and Treasurer, Merchants Refrigerating Company, New York. 1911–40; Consulting Engineer, Merchants Refrigerating Company, New York, 1940–45.

Author of several technical papers; Chapter 53, 1946 Applications Volume, ASRE Data Books.

Member, ASME—Chairman Joint Committee; ASRE—President, 1924; Honorary Member, ASRE, 1944; Fellow, ASRE, 1947. Received the Distinguished Service Award from Lehigh University Alumni Assn., 1949.

Retired from active business.

Brine Pipe Lines

The central station systems in Boston and New York are brine systems. The brine system requires thorough insulation of all mains, large piping, and proper pumping equipment. It has the advantage of retaining all the ammonia at the power house. Any system is not free from the possibility of leaks which may cause a temporary shutdown. One of the systems in New York, which supplies about 18 city blocks, has made provision against complete stoppages.

There is a network of brine mains ranging down from 12-in. pipe. The system is composed of four sections separated by remote control electric gate valves. The loss of brine, due to any considerable leak, automatically operates a pair of the electrical gate valves, thus isolating the affected section. The rest of the system may be kept in operation while the leak is being repaired. **Fig. 1** shows the monthly load on a brine pipe line in New York City, together with the kilowatt hour consumption. One large office building on this New York line, a building housing about 16,000 persons, is furnished with refrigeration for its drinking water. **Table 1** shows cost of operation of this system.

Table 1. Cost of Producing Refrigeration, Dollars per Ton-Day (1947)

Year	Ton-days of refrigeration	Total cost†	Cost per ton-day
1935	87,090	$44,374.43	$ .50
1936	83,301	45,464.27	.55
1937	90,187	46,780.15	.52
1938	95,410	51,099.08	.53
1939	90,574	50,221.57	.55
1940	85,064	49,784.32	.59
1941	104,907	55,706.04	.53
1942	91,307	57,225.63	.63
1943	99,507	55,733.53	.56

† Exclusive of cost of franchise and rental.

Brine is pumped with centrifugal pumps and accurately metered with a recording

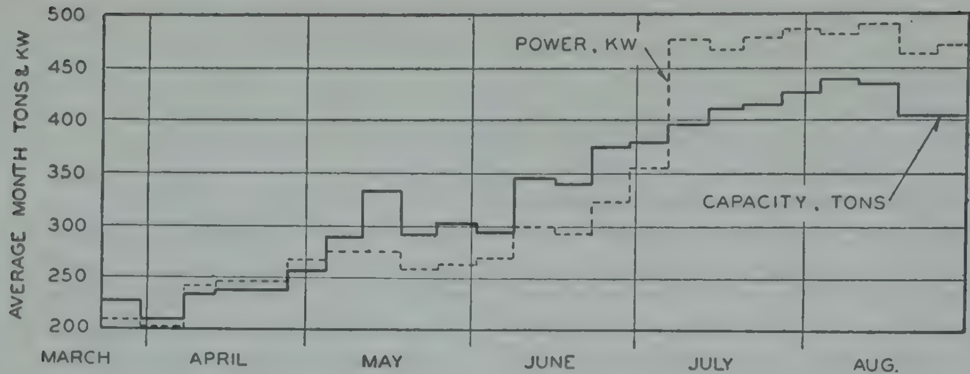

Fig. 1. Load on Brine Pipe Line in New York City.

Venturi meter. Temperatures of the flow and return brine are measured with recording thermometers. These, in turn, are checked with an accurate electric resistance thermometer. The power plant, which also furnishes refrigeration for a cold storage warehouse, is equipped with recording liquid ammonia meter which gives accurate information on the total refrigeration produced, and furnishes a check upon the refrigeration calculated from the combined pipe line and warehouse brine tonnages.

The brine is delivered at about 0 F to 400 refrigerators varying in size from 200 to 15,000 cu ft, aggregating more than 2,000,000 cu ft, of which about one-third is freezer space. The rest is space used for storage of foods and other goods above the freezing point. The plant has two-stage horizontal ammonia compressors in a single engine room. This location is the result of a consolidation effected after several years of operation with three cooling systems at as many points on the line.

The largest mains, 4 to 7 ft below the surface of the city streets, are of standard weight wrought iron pipe, with bell joints caulked with lead. Smaller mains are flanged. There is a normal loss of about 25 gal of brine daily on this line, which will run higher if there are leaks—items of some expense in the course of a year. Specific gravity is kept at 1.23, and brine is kept slightly alkaline and otherwise treated to prevent corrosion. The velocity in the mains reaches as high as 250 ft per min, about 4000 gal per min being the maximum flow required in summer, against a head of 120 ft or more. This requires about 100 hp at the motor. In event of a shutdown of the refrigerating plant, the pipe line has some storage capacity, and an added safety factor is provided in a large reservoir of cold brine held for emergency, in order to make up the loss of brine as quickly as possible.

In Boston, air conditioning is provided restaurants by the return brine from the street system, which is substantially warmer than the supply brine. The brine flow is controlled by the solenoid valve at each installation. This pipe line also operates certain air conditioning units wherein a secondary refrigerant receives its refrigeration from the street line service through a simple heat exchanger. Another interesting feature of this layout is the use of the street brine in the condensers of ammonia boosters, which supply low temperature refrigeration to a quick freezing machine.

Ammonia Pipe Lines

The pipe line systems in Los Angeles and St. Louis use direct expansion ammonia. At Los Angeles there is a network of liquid and suction lines, some 16 miles in total length. The piping involves many pairs of sizes, and many sizes of conduit. Since none of this pipe is insulated, a suction superheat of as much as 40 F is not unusual. The expense of piping was further reduced by laying it within 3 ft of the surface, in a trench as narrow as possible, perhaps 18 in. wide, to reduce repaving costs. Many obstructions were met with in laying these pipes, so that in places excavation to much greater depths has been necessary. Cement

tiling conduit was used as indicated in **Fig. 2,** which also shows a section of a manhole. All lines were welded and tested to 300 lb per sq in. with air, and then with ammonia to 200 before the top tiling was laid and the ditch filled in.

All-steel expansion joints were installed on straight runs, but in other places, where dips occur in the line, no particular precaution was taken to absorb expansion movements. Where a branch line is taken off at a 90° angle from the main line, a small expansion loop is provided, for the line is welded in on a tangent. In such cases, a wider tile is used on the branch line to allow side movement of the pipe and to compensate for the contraction or expansion of the main line.

Shut-off valves are installed on both lines in all manholes, with a 1-in. valve on each side of the shut-off valve. All valves larger than 2 in. are provided with round flanges, having not less than six bolt holes. As there are heavy trucks and street cars passing over the lines at many points, vibration is set up in the ground, making it necessary to give special attention to all fittings installed underground to prevent service interruptions due to breakage.

When it is necessary to replace a pipe which has a fairly straight run, the cost can be reduced by building a trench about 30 ft long and removing the top part of the conduit. A 6-ft pipe spool is then cut out

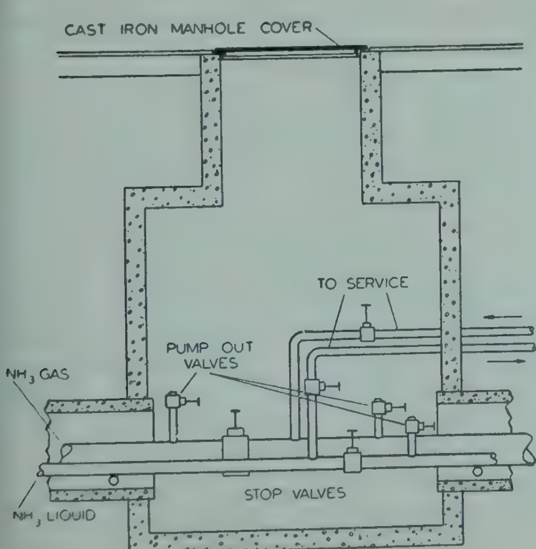

Fig. 2. Section of Manhole in Pipe Line.

of the line which is to be replaced, and a steel adapter with a pointed nose is welded on the end of the line. A steel cable is attached to the adapter. At the other end of the line to be removed, a small ditch is made, if no manhole is available, and that line is then cut and the steel cable fastened to the end.

A hand winch or truck is attached to the cable at the adapter end, and the pipe line is then pulled out of the conduit. The cable on the opposite end is fed into the conduit with the pipe, to be used later for the pulling-in process. The new line is then welded up in the street, tested, and the adapter placed at the end which is going through the conduit first, and the operation is reversed from the other end. This operation is satisfactory on pipe sizes up to 4 in. However, precaution should be taken that a steady pull is applied during the pulling operation; if not, the welds are likely to rupture. In several instances, as much as 600 ft of 4-in. pipe has been replaced in this manner, and when one considers that the average cost per running foot of excavating and back filling and replacement of broken pavement costs approximately \$1.55, he realizes that a large saving is made by this method.

The plant supplying ammonia to the Los Angeles pipe line has a capacity of 850 tons available for this service, and in the day's course of a normal year about 100,000 tons are used. Losses of ammonia are small, and on the order of those found in any well maintained refrigerating system.

A summary of the essential operating characteristics is as follows:

1. The suction pressure is maintained at an average of about 14 lb per sq in. with a maximum of 20 and a minimum of 7. The suction pressure is reduced each night so that if any freeze-out occurred during the day, this liquid is evaporated under the reduced pressure, thereby cleaning up the suction line for the following day's operation.
2. The pipe line liquid pressure is maintained at a maximum of 185 lb per sq in., by throttling the liquid lines when the head pressure exceeds that. At no time is the liquid pressure al-

lowed to go below 125 because, at certain points in the line, vapor will form when the plant pressure drops below 125. This minimum pressure level is maintained by either reducing the number of condensers or the quantity of water to the condensers, since a satisfactory liquid pump to boost the pressure to 125 when the head pressure drops lower than this has not been found.

3. The liquid must be subcooled. Maintaining it at a temperature between 55 F and 65 F, will actually reduce any tendency to form gas in the restricted portions of the line and at the point of throttling, when reducing the pressure in the liquid line to 185 lb per sq in.

Normal **service** to the customer is for temperatures of 32 to 40 F on a flat rate, in most cases based on space and length of contract time. If freezer service is required, the rate is 50 per cent higher. The company **charges** its customers in two ways, by a flat rate and a metered rate. There are two types of meter: (1) A liquid ammonia meter which measures the refrigerant supplied to the customers, and (2) an hour meter which records the number of hours the equipment is in operation and furnishing refrigeration. The flat rate is used in restaurants, markets, small packing plants, and in a few air conditioning installations which operate long hours nearly every day of the year. The liquid meter method is used in large air conditioning systems. The time meter is used in small air conditioning installations.

More than 100 customers are supplied with requirements of from 0.1 to 135 tons each. Many of these requirements are for comfort air conditioning in restaurants and stores.

Inspection and Maintenance

In order to **eliminate oil,** a source of trouble in the system, an elaborate separator is used after the compression discharge line. A vertical condenser was put in line with about 2000 sq ft of surface, to receive all the discharge gas near the bottom, leaving the other side at the top. Here the 2-in. tubes act as baffles and separate the oil. Care is taken to avoid any condensation of the ammonia by regulation of the temperature of the water to this condenser, which has a separate pump.

All manholes are inspected semi-weekly to detect **ammonia escaping** from fittings or mains. Particular attention is paid to the depth of water in the bottom of the manholes. If water is present to such an extent that it will enter the pipe conduit, it is immediately pumped out to prevent an accumulation of frost and ice in the conduit.

If **frost** appears on a suction gas main, the service man is notified to check on all services to determine which service is frosting out. Customers are not allowed to operate expansion valves, and if for any reason the service goes off between inspection rounds, the customer notifies the power plant and a service man is sent out to correct the trouble.

The maintenance department is in full charge of the installation of new services and equipment, and is also responsible for the general maintenance work throughout the system. If a break occurs on the underground line, the shut-off valves on the suction gas and liquid lines located on each side of the break are closed. All shut-off valves leading to this area are also closed.

A portable $3\frac{1}{2}$-in. × $3\frac{1}{2}$-in. enclosed type vertical ammonia compressor unit, with high side complete, driven by an 18-hp gasoline engine mounted on a trailer, is sent to the location. This portable equipment is furnished with a 10-in. suction blower, having two 6-in. rubber hoses of sufficient length to be placed in the manhole and pipe line conduit, so that the escaping ammonia gas can be removed.

If you searched this chapter for something which was not found in it, please let the editors know.

59. COOLING OF ELECTRODES IN WELDING

THE welding industry deals with heat, but the actual heat of fusion is only a small part of the total heat created in a resistance welding machine **(Fig. 1)**.[1] Unwanted heat is built up in the electrodes, as in **Fig. 2**, and must be dissipated or carried away to prevent the rapid deterioration of the copper (or copper-alloy) electrodes, which are commonly used for welding all metals. Aluminum and steel are the most common materials welded by this process. And where there is unwanted heat, refrigeration will always be a factor.

In the ordinary **resistance-welding** of iron and steel, tap water will provide satisfactory cooling in most cases. However, in the **"pulsation welding"**[2] of steel and in the new battery welders, refrigeration has been found to be extremely helpful in the rapid removal of the large amounts of heat generated in the electrodes.

In many cases **aluminum welding** would have been impractical had not refrigeration come to the rescue. The average number of consecutive spot welds obtainable at one time was 20 or less, because after a few welds the electrodes became extremely hot. This accelerated the natural affinity of copper and aluminum, causing ever increasing particles of aluminum to stick to the electrodes.

This undesirable phenomenon is called "pick-up," and when it occurs, welding must be discontinued until the electrodes have been dressed—cleaned with a file and/or a fine abrasive cloth. Otherwise weak, unreliable, and pitted welds would result.

A. L. MUNSON, Author Chapter 59. Born 7/8/07 in Brooklyn, N.Y. Educated at Lehigh University, ME; Extension courses at Univ. of Pennsylvania, Rutgers Univ., Long Island University, and Alexander Hamilton Institute. Formerly with Lipman General Refrigeration Corp., Beloit, Wis., 1936–38; Westerlin and Campbell, Chicago, Ill., 1938–42; Frostrode Products, Detroit, Mich., 1942–44; John G. Marshall, Inc., Brooklyn, N.Y., 1944–45; York Distributors, Inc., New York, 1946–49.
Author, Chapter 54, 1946 Applications Volume, ASRE Data Books.
Member, ASRE—Detroit Section Treasurer, 1944.
At present, Sales Manager, York Distributors, Inc., New York, N.Y.

When a rivet is used to fasten two sheets of metal, any inspector knows that the rivet goes all the way through because he can see both ends of it. And he knows that for given sizes there will be a corresponding predictable strength.

But since there is no accepted standard way of visually inspecting spot welds, the **strength** of a series of welds must be determined from one or more sample welds, which are pulled apart as specimens, to test the strength of a run. In order to be sure, therefore, that the other welds in the run are of equal size and strength, extreme consistency must be provided. This involves control of welding currents, welding time,[3] and surface preparation, but must also include the profile of the electrodes, and fairly constant face temperatures. A small variation in profile would make a big difference in weld strengths, and wide variations in face temperature would also cause erratic results.

It is this problem that has often made the use of refrigeration so desirable, even

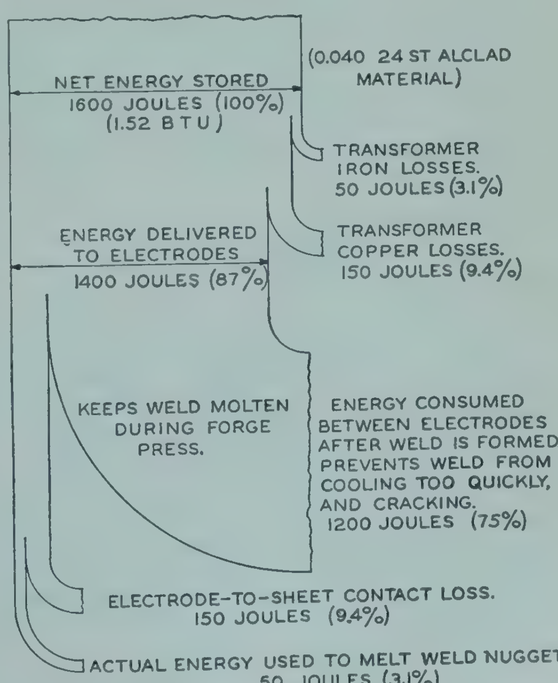

Fig. 1. Distribution of Energy Flow for a Single Aluminum Spot Weld (on a stored energy machine).

in steel welding, because mushrooming of electrodes can virtually be eliminated with adequate cooling. Thus there are two very good reasons for the use of refrigerated electrodes, for achieving better quality control and for greater consistency.

In Fig. 1, the total energy needed to form one weld is graphically shown. Note that only 3.1 percent of the total energy is actually used to melt the weld nugget. So, while resistance welding is a very economical and efficient method of fabrication, it is not too efficient in energy use,* and the resulting unwanted heat is considerable.

Fig. 2 illustrates the basic **functions** of **heat** in making a resistance weld. The weld nugget is formed because sufficient current passes through the surface resistance always present between two sheets of metal, thus causing enough heat to melt the metal at this point. With properly shaped electrodes and correct pressure, the nugget will always be in a direct line between electrodes. Sufficient electrode pressure must be exerted to contain the molten metal until it fuses and cools; otherwise extrusions and cracking would result in a poor weld.[4]

But there is also a **resistance to current flow** between the electrodes and the sheets being welded. Most of the heat so caused is unwanted. To determine the cooling load, for all practical purposes, the total input energy (in Fig. 1, 1600 joules) must be considered as heat to be removed by the cooling medium.

Since 3600 joules = 3.412 Btu

$$\frac{3.412}{3600} \times 1600 = 1.52 \text{ Btu per spot}$$

This has been determined by experimentation as well as by a long accumulation of production experience.[5] In Fig. 1, it would appear that the **total load** would be a maximum of 83.9 percent of the total input energy. However, additional loads are added (particularly at low temperatures) by the radiation from electrode holders and welder arms, so that it is never safe to consider anything less than 100 percent of the total energy in the transformer secondary circuit. (By determining the net weld forming energy from **Fig. 7** and dividing it by 0.031, total input energy for various shear strengths can be readily determined with fair accuracy.)

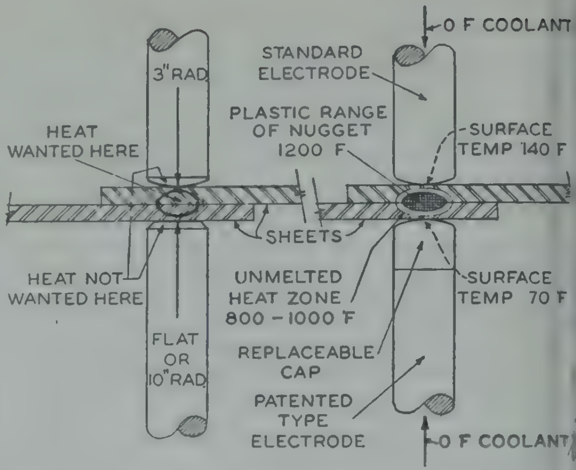

Fig. 2. Approximate Temperature Relationships in Aluminum Spot Weld.

From this, it will be relatively easy to calculate approximate hourly loads. For instance, a welder welding two pieces of 0.040-in. 24St Alclad material, at a rate of 60 spots a minute, will require: $60 \times 60 \times 1.52 = 5472$ Btu per hr cooling capacity:

Total heat input, Btu × spots per min × 60 = Btu per hr.

This will usually work out very well for aluminum; but it may not always be accurate enough for steel welding. However, it will always be a safe guide. And for aluminum welding 1.5 to 1.7 Btu per spot will provide a good rule of thumb, for light and heavy gage work respectively.

In **Fig. 3**, are shown three **types** of **electrodes** in common use. A is a conventional offset type which is most difficult to cool because the coolant is so far from the source of heat, and because there is so little effective surface exposed to the refrigerant. By using a 0 F medium in this electrode, face temperatures (the equivalent of tap-water cooling of B) can be held low enough for successful welding. B is the conventional electrode drilled out ⅜ in. with a ¼-in. O.D. coolant tube. It can be successfully cooled with maximum coolant flow. If the tube is too far away from the face, a steam pocket may develop, reducing the cooling effect. C is the patented type electrode coming into wider use. It has been designed for

* Spot welding costs are approximately $0.004 to $0.005 per spot (per Vought-Sikorsky).

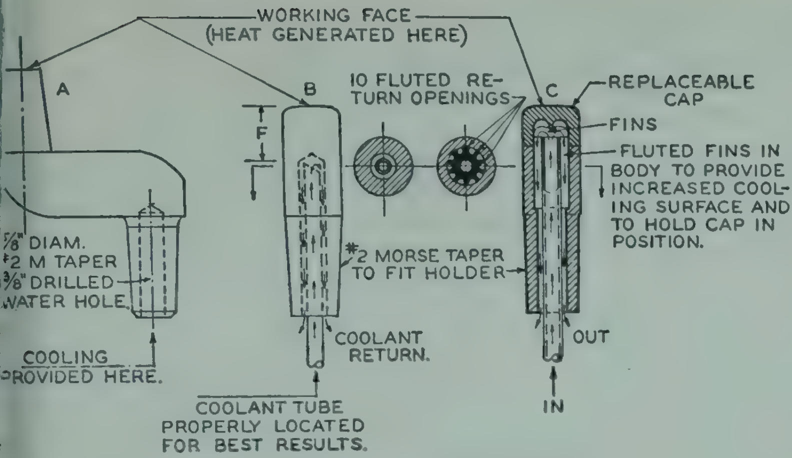

Fig. 3. Electrodes in Common Use.

greater thermal efficiency, and incorporates a replaceable finned cap which provides six to ten times more effective surface.

From 1.5 to 2 gal per min should always be circulated through each electrode. Care should be exercised to assure equal flow to each electrode. In steel welding, as much as 5 or 10 gal per min should be used, according to the heat generated, and the size of the electrode.

Another benefit of cooling by refrigeration is that as the temperature is reduced, the electrical resistance of copper decreases while the thermal conductivity increases.

Fig. 4 is an interesting study of the relationship of all the forces involved in making a spot weld in relation to time and face temperature, when 0 F cooling medium is used.[7] An immediate heat gain in electrodes is to be noted when welding current is on. This is an actual oscillographic record of electrode force and welding current in relation to cycles of time. It will help to correlate the factors affecting spot welding, and illustrate the short time available for cooling between welds.

Fig. 5 shows the effect of coolant temperatures on the **number of welds** that can be obtained between cleanings (before pickup). The results of every investigation show that refrigeration can be effective in retarding pick-up and prolonging tip life, under good welding conditions.[6] The slope of these curves has been pretty well established; however, these results were obtained under laboratory conditions of control, and actual results in production may be considerably lower on the scale.

Fig. 6 shows the importance of maintaining maximum coolant flow.

Fig. 7 shows weld-forming energy required for various shear strengths. In order to estimate **cooling loads,** one of the following sets of conditions must be known:

1. Weld time, secondary amps, and volts (under maximum conditions)
2. Weld time, secondary amps, and maximum ohms of resistance anticipated between electrodes
3. Maximum secondary joules, or Btu
4. Cooling medium flow and temperature difference* between entering and leaving welder.

It is best to add 15 percent or more, when more cooling is desired than is being provided by existing water. This will offset increased radiation losses from holder and arm, which must of necessity be in metallic contact with the electrode in order to carry the current.

Factors in Application

There are many variables which will affect the successful application of refrigeration to resistance welding electrodes, including the following:

The **condition of the electrode tips** can seriously affect the quality and rate of welding. If the electrode face temperature rises, pickup is increased and the time between cleanings is reduced. Such a condition may be caused by inadequate refrigerant flow (too high a coolant temperature), dirty material, or action of the electrode as a current switch,[8] with resultant arcing as it leaves the work (although this is almost never visible), and skidding of the elec-

* Seldom more than 2 or 3 F.

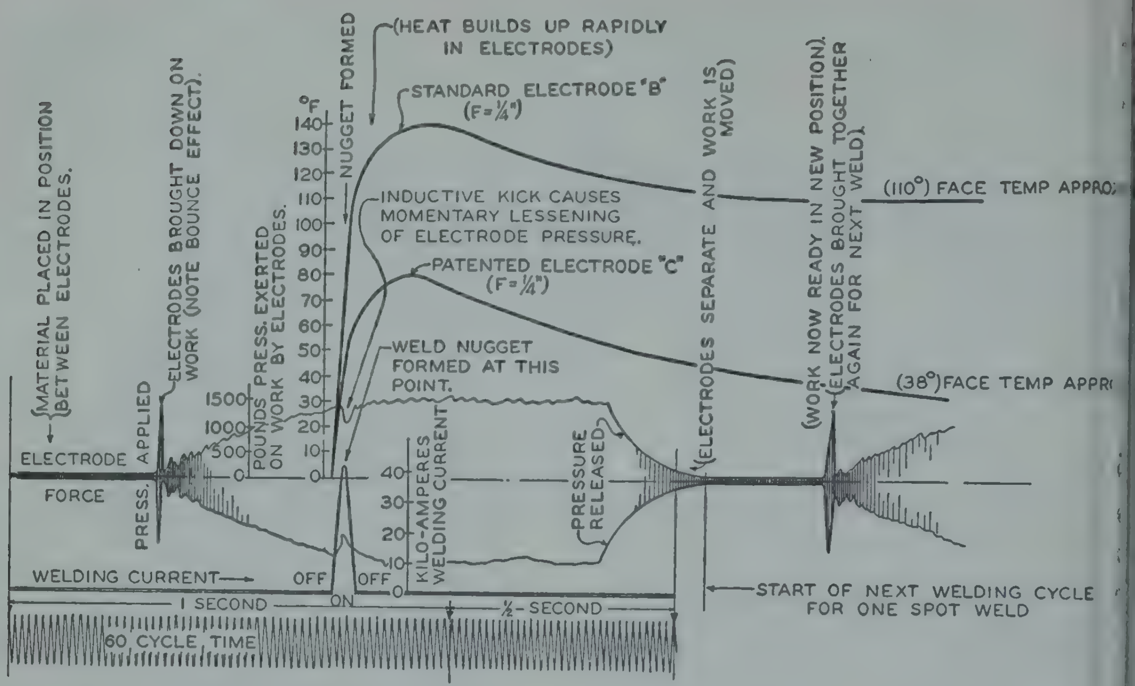

Fig. 4. Oscillographic Record of Electrode Force and Welding Current with Temperature Curve Superimposed (2 gal per min of 0 F coolant circulated through each electrode).

trodes due to excessive deflection of the welder arms.

The **surface preparation** of the work to be welded is extremely important in aluminum welding. It is impossible to remove all the oxide from the aluminum surface in the presence of air. So the main object of surface preparation is to reduce the oxide to a known and consistently constant minimum.

The **control** of current, time, and pressure must be left to the welding operator. But these must be accurately controlled, and in the right relation to each other and to the work.

The **temperature** of the **coolant** is often dependent upon the desires of the operator after he has done some experimenting. However, in general, from 0 to 10 F is best for aluminum welding, and 40 F for steel welding, and for application to gun welders.

Types of **refrigeration systems** should be carefully considered. Some method of indirect cooling employing an anti-freeze solution will be found most practical. Direct expansion systems have been tried but have not been successful so far, because of the introduction of atmospheric moistur into the system when an electrode changed. In some cases, a central syster can be advantageously employed, wher the location and arrangement of weldir machines will be permanent and wher they are grouped together. But in mos cases plant flexibility is extremely impo tant and small individual cooling units ar used. This arrangement permits eac welder to operate independently. It woul be poor economy to use a large central sy tem to cool two or three welders during slack production period.

The weld nugget should be between 4 to 80 percent of the total thickness of th sheets being welded.[9] Too large a nugg will enlarge the heat affected zone to th point where no amount of cooling wi suffice.

Where welding cables, transformer and/or ignitron tubes are cooled in add tion to the electrodes, sufficient addition capacity must be provided to maintai efficient electrode cooling in spite of th added load. Normally the coolant or chille water would be circulated first through th

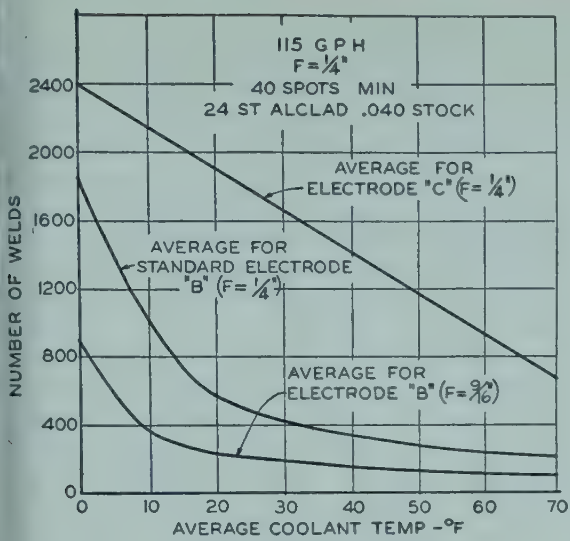

Fig. 5. Effect of Coolant Temperature on Electrode Tip Life.

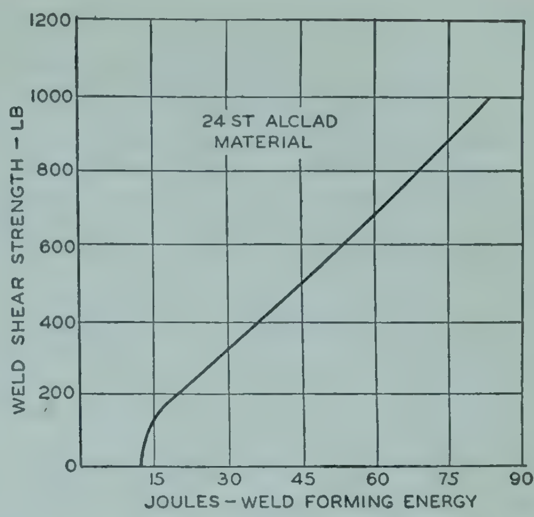

Fig. 7. Weld-Forming Energy Required for Various Shear Strengths.

electrodes and then the other equipment. Sometimes a parallel circuit, controlled by a hand valve, is used to provide the small amount of cooling needed by this extra equipment. This arrangement, which allows the welder to be entirely independent of water supply, has been used in portable welding equipment and repair carts.

In **selecting a coolant** it is essential that it have a high specific heat, good flow characteristics at lowered temperatures, a high flash point, and a safe freezing temperature

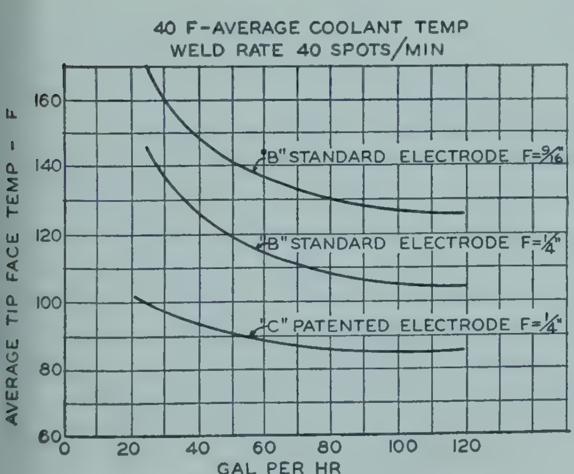

Fig. 6. Effect of Coolant Flow and Distance between Face and Coolant = F.

to prevent clogging or rupture of evaporator coils.

A $\frac{1}{3}$-hp turbine type **pump** with a capacity of 5 gal per min against 35 lb per sq in. head will be required to handle the coolant through each welder. This type of pump has been found most satisfactory for this application since it adds a minimum of heat, in aluminum work. In steel welding, pumps must be chosen to operate against as much as 50 or 60 lb per sq in. pressure. In either case, it is important that maximum flow is obtained through the electrodes.

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If you searched this chapter for something which was not found in it, please let the editors know.

SECTION VII

COMFORT AIR CONDITIONING

Walter A. Grant, Associate Editor and Author, Chapter 60. Born in Brooklyn, New York. Educated at Amherst College, 1921–23; Columbia College, AB, 1926; Columbia University, BS, 1927; ME, 1928.

Formerly, Application and Research Engineer, Carrier Corp., Newark, N. J., 1928–35; Eastern Regional Chief Engineer, Philadelphia, Pa., 1936–43; Director of Application Engineering, Syracuse, N. Y., 1943–47; Director of Research, Syracuse, N. Y., 1947 to date.

Co-author, "Modern Air Conditioning, Heating and Ventilating," Pitman Publishing Corp., 1940; author of technical papers presented at ASRE and ASHVE national meetings; contributor to *Refrig. Eng., Heating, Piping and Air Cond., Elec. Lt. and Pr.*, HP and ACCNA Bulletin, ASHVE Guide. Associate Editor Section VII and author, Chapter 55, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engineers, ASHVE. Registered Professional Engineer, States of New York and New Jersey.

At present, Director of Research, Carrier Corporation, Syracuse, N. Y.

Chapter | Page

60. COMFORT AIR CONDITIONING

THE purpose of this section is to offer practical guidance in the design of **comfort air conditioning** systems. The authors of all of the chapters are engineers who have been engaged many years in the business of surveying buildings, calculating loads, applying manufactured equipment or components, and designing integrated systems to produce comfortable conditions indoors all year round. Each author in his field of endeavor is a specialist who knows well the fine points which distinguish the excellent job from the mediocre one, and who knows the pitfalls which may so easily jeopardize results.

All comfort air conditioning is functionally similar, and, from the viewpoint of basic application principles, is very fully treated in the basic volume of the *Refrigerating Data Book*, Part VI (1949). No attempt is here made to duplicate this material, to which the reader is referred; on the contrary, the purpose of this section is to develop the differences which arise out of the several kinds of applications. Each chapter is written in answer to the questions: "What are the characteristics and peculiarities of this particular application which pose problems to the air conditioning engineer? How can the problems best be solved?"

For those readers desiring further information there is a wealth of material in the existing literature. For this reason, the following bibliography is presented with no implication that it is complete, but merely that it is representative of the best recognized sources.

References to the Refrigerating Data Book

(Basic volume, 6th Edition, 1949)

Subject	*Chapter*	*Page*
Theory		
Theory of air conditioning	35	583
Theory of refrigeration	1	3
Glossary of terms	41	659
Air Conditioning Data and Practice		
Load calculations and equipment selection	37	615
Fans and ducts	36	599
Air distribution; filters	38	629
Small comfort systems and units	39	637
Control	40	645
Refrigeration Data and Practice		
Refrigerant properties	8	187
Refrigerant tables (Freon-12, -11)	7	107
Compressors	23	403
Small units	31	485
Condensers	24	421
Evaporators	25	447
Pipe and piping	16	279
Motors	20	345
Servicing	34	563
Oils and lubrication	17	299

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61. DEPARTMENT STORES

THIS chapter, dealing with the air conditioning of department stores having a gross area of approximately 40,000 sq ft or over, distributed on two or more floors, will not repeat the basic theory of air conditioning design. The reader is referred to appropriate sections of the *ASRE Data Books* and to Chapter 29 of the 1950 *A.S.H.V.E. Guide*, on central stations for comfort air conditioning.

Design Conditions

Conditioning systems should be of such capacity that a design condition of approximately 78 F and 50 percent rh is not exceeded on an average peak day. A maintained temperature of 75 to 76° is desirable and feasible under most load conditions. The higher figure represents practical design under average peak conditions, for reasons of economy in first cost. A definite recommendation for peak design condition is not presented because of its relation to the duration of peak weather in any locality, and the variation in the method of computing the heat balance, including such variables as the heat storage of the structure.

Where refrigeration or air supply is deficient, the results from the system can be significantly improved by extended hours of operation. Extended after-cooling has been found to be just as effective as extended pre-cooling. Such operation reduces the excess heat from the structure and merchandise which are normally above room air temperature and does not necessarily result in starting the following day's operation at below design temperature.*

Heat load. The present trend in department store design is to build stock rooms, small shops, and service areas around the perimeter of the building, leaving the central floor open for selling. In general, the use of daylight is decreasing and the use of artificial light is increasing. The result of the above is to establish an **internal sensible load** which is substantially **independent of outside temperature.** Removal of sensible heat for floors so arranged becomes a year-round requirement and means must be provided for either cooling by outside air when the temperature permits or for continuing refrigeration even in cold weather. Some upper floors of stores which have not been recently remodeled are less critical in this respect, but the tendency to close in the perimeter is so pronounced that design on a 20-year assumed life should consider this possibility.

Figures for watts per sq ft and sq ft per person will vary widely with the type of store and its location. The following tables will serve as an approximation:

	Watts per sq ft
Basement	1 to 2
First floor	4 to 5
Upper floors, women's wear	3
Upper floors, housefurnishings	2 to 3

Fluorescent lights are rated on the power consumption of the tube only; power consumption of the auxiliaries should be included in the heat balance.

CHARLES S. LEOPOLD, Author Chapter 61. Born 5/8/96 in Philadelphia, Pa. Educated at University of Pennsylvania, BS and EE, 1917. Consulting office established in 1923. Air conditioning design projects include: U. S. Capitol and (old) House Office Building, Washington, D.C.; Pentagon Building, Arlington, Va.; many department stores and commercial buildings.
Co-author of "Bronchial Asthma and Allied Allergic Disorders"; author of a number of articles on air conditioning, including "Mechanism of Heat Transfer Panel Cooling, Heat Storage"; chairman, ASHVE Publication Committee for 1946 "Guide"; Author, Chapter 56, 1946 Applications Volume, ASRE Data Books.
Member, Sigma Xi; Fellow and past president, ASRE; Member, ASHVE; Fellow, Royal Society of Arts; Member, Franklin Institute.
At present, consulting engineer, Philadelphia, Pa.

* Reference: "Hydraulic Analogue for the Solution of Problems of Thermal Storage, Radiation Convection and Conduction," presented ASHVE SemiAnnual Meeting, June, 1948.

	Sq ft per person
Basement, metropolitan area	15
Basement, other, with occasional peak	20 to 40
First floor, metropolitan area	20 to 25
First floor, suburban	25 to 50
Upper floors, women's wear	50 to 75
Upper floors, housefurnishings	100 or more

The trend toward increased use of escalators in large stores will ultimately increase concentration of people and lighting of upper floors.

Heat concentrations, such as that in a lamp department, are frequently encountered. In a store with a high ceiling, small difficulty is encountered, but where such a department is placed on a balcony or in a walled-in space, special design is merited.

Restaurants and lunch counters require special treatment (Chap. 64). Where food service is a small portion of the total load, areas in which food is served can be supplied from central air cooling apparatus. In some cases it is advisable to provide a forced exhaust equivalent to the supply in the restaurant area because of the possibility of odor leakage. If, however, the dining area is large in comparison with the other air cooling needs, separate apparatus is frequently justified.

Odor problems in a department store can usually be met economically by the use of adequate minimum outdoor air. There are relatively few unusual sources of odors and recommendations of the *Data Book* (basic volume) will, in general, govern. Musty odors, sometimes associated with store conditioning, are usually due to the maintenance of higher than recommended humidities. If humidities are not permitted appreciably to exceed 50 percent, there will be no unusual requirements for outdoor air.

In fact, outdoor air within economic limits will not compensate for a high inside dewpoint.

Diversity. In general, the branch **ductwork** in any particular area should be designed to meet the calculated peak load. The size of the branch duct should also be checked against possible future use of the area, as it is a relatively inexpensive point at which to supply flexibility. If a separate means of air cooling is provided for each area, each system must be of adequate capacity for peak. Should more than one area be served from the same air cooling device, a reasonable diversity factor may be assumed, based on the expected simultaneous load of the areas served. In general, this diversity will apply to people and outside air, not to lighting except on floors used for furniture display. The actual required refrigeration can be based on the simultaneous peak load of the air cooling devices served.

Diversity factors should be obtained from an analysis of the exact proposed application. In applying diversity to a central air cooler, whether air washer or coil, the design should be cross-checked against weather data and power costs to determine whether or not surplus air capacity above dehumidified is justified by the use of outdoor air, in lieu of refrigeration, in other than the calendar summer months. Where an adequate supply of outdoor air is not provided, conditions during the December peak can be quite unsatisfactory as there is a general reluctance, both economic and otherwise, to operating compressors at this time.

Structural Factors

The general plan of a department store air conditioning system is influenced by the nature of the ceiling, location of existing shafts, the availability of space which is not readily accessible for other purposes, the strength of the structure, and the shape of the floor. The location of air conditioning utilities can frequently follow the major circulation provided for customers. This, however, is far from being a general rule.

Air ducts. With the modern type floor previously described, the problem of ductwork for supply air distribution is rendered somewhat more costly but otherwise simplified, as the ducts can pass through the service areas adjacent to the perimeter. Perimeter distribution has the following advantages:

1. It makes for flexibility for departmental changes.

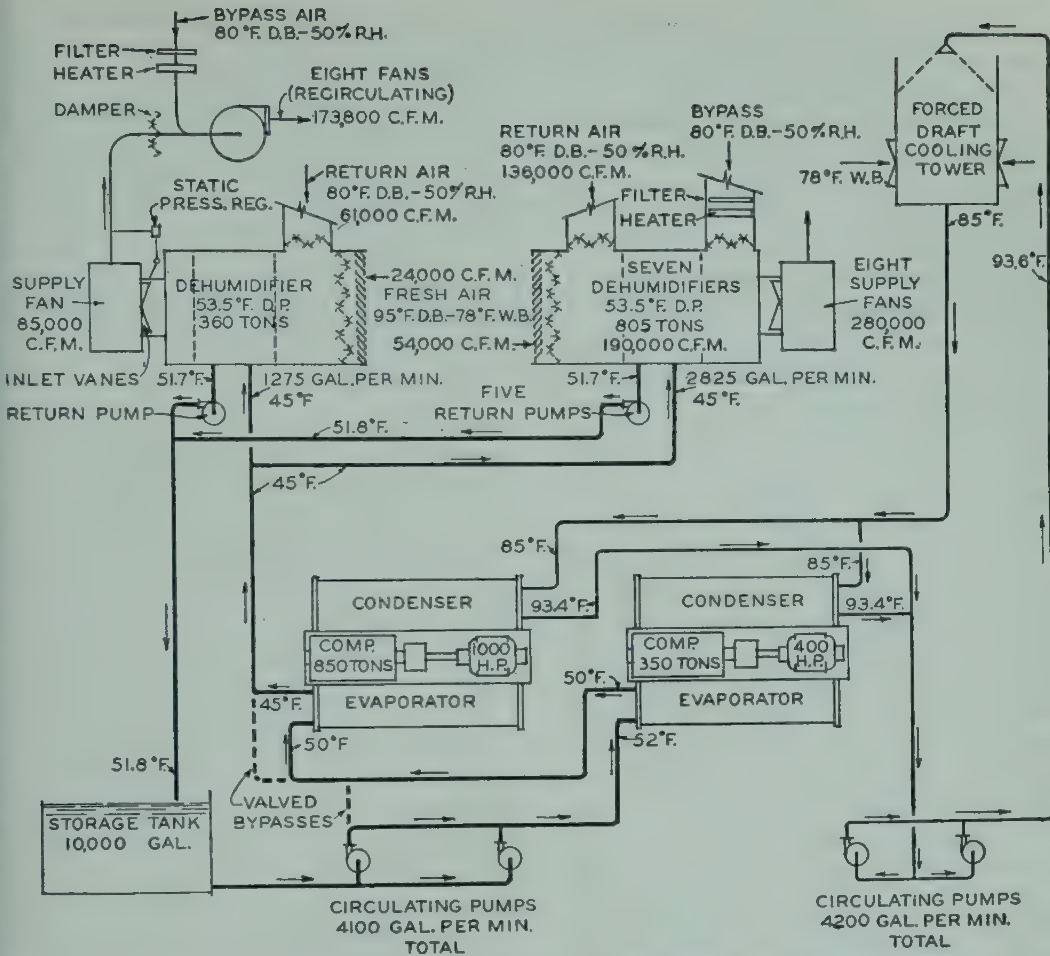


Fig. 1. Schematic Layout of Air Conditioning System in the Gimbel Store, Philadelphia, Pa., 1937. (Values shown are for peak total load conditions. Normal operation is 76 DB—50% RH-51° apparatus dewpoint.)

2. Ducts of better aspect ratio can frequently be used.

3. Air supply to individual fitting rooms, stock rooms, and work shops is readily provided.

4. Only the air outlets show from the general customer area.

For essentially open floors, distribution can be obtained from a centrally located duct.

Ducts placed close to the ceiling are relatively inconspicuous when painted to match the ceiling. Plaster furring is sometimes justified but is not always desirable, regardless of cost, because of the increase in the apparent size of the duct. Where ducts must pass under small beams, appearance can frequently be improved by running curtains from the top of the duct to the ceiling so that the duct appears as part of the ceiling construction. Where bays are framed by beams in both directions, satisfactory appearance can be obtained by running the duct directly adjacent to the column instead of in the middle of the bay. The duct can run on either one or both sides of the column and in either case it is frequently desirable either to furr in or complete the ductwork to the ceiling with metal.

When ducts are held close to the ceiling, care should be taken in the placement of outlets which will frequently have to be toward the bottom of the duct in preference to the center in order to avoid ceiling obstructions and to obtain the proper limitation on the length of blow. Air noise originating in the branch ductwork is

seldom a factor in department store conditioning as air pressure and velocity are limited by other considerations.

For department store work it is seldom advisable to supply air at or close to the dew point temperature. The **disadvantages** of a **large temperature difference** between room and supply air are:

1. Increased control requirements as between areas with variable loads.
2. The need for more insulation due to temperature rise on the long duct runs.

The use of **bypassed air** simplifies the control problem by reducing the potential difference in temperature between two unevenly loaded areas served by the same system. It also reduces the difficulties due to temperature rise in the ducts. Increased size of fan and branch ductwork for the utilization of bypassed air has the objection of higher cost.

In many large department stores, floors for women's wear are subdivided into individual shops. For this application the use of a small difference between supply air and room conditions will frequently obviate the need for individual control.

All long duct runs should be carefully studied and designed for temperature rise. Even with distributing ductwork in conditioned space, insulation is frequently required for maintenance of uniform conditions and prevention of over-ventilation or under-ventilation in areas away from and close to the fan, respectively.

As a generalization, the design of the return system is important only as to adequate size and the absence of local drafts. The velocity of approach to the return opening in any part of the store, at the working level, should not exceed 100 ft per min as a high limit.

The building should in all cases be checked for means of egress for the maximum amount of outdoor air introduced in other than peak summer weather. In view of the present trend of eliminating windows in department store design, **relief fans** may be required. They can be installed as either return fans with a branch to outdoors or as simple relief fans. Control can be effected either by interconnection with the outdoor air damper or by means of static pressure regulators set to maintain a predetermined excess of pressure indoors.

Air Cleaning

Whether air cooling be by means of an air washer, coils, or coil plus spray, auxiliary means of air cleaning are usually desirable. Coils should be protected by **filters** because of the serious difficulties which can be caused by an accumulation of lint. It is advantageous to filter all bypassed air in order to prevent lint accumulation in the heaters, fans, and branch ductwork. The life of these filters can be greatly prolonged by the use of specially made screens for the return air inlet. Such screens are most effective if installed in the selling areas where the visible accumulation of lint will force proper maintenance.

In some cities there is very little soot in the air—notably those burning only gas for fuel—and in these cases a filter is not definitely required prior to or following an air washer.

There are definite limitations to the air cleansing ability of the impingement type filters. In localities where outdoor air contains large quantities of soot, the interior can be effectively protected by the use of electrostatic precipitators. Even though the supply air be substantially dust-free, discoloration around air outlets will occur, largely due to the recirculation of dust released within the conditioned space. With electrostatic precipitation, the discoloration is less and can be more readily cleaned.

Stationary cleanable filters are difficult to maintain, particularly when they must be trucked through sales areas enroute for cleaning. This disadvantage can be partially corrected by utilizing filters which can be reasonably well cleaned in place by a heavy duty vacuum cleaner. In any case, it is advisable to provide adequate space and means of cleaning directly adjacent to the filter bank.

Representative Practice

Depending on local conditions and economics, air can be cooled and dried by any of the well-known means, such as cold well water, cold surface by refrigeration, adsorbents and absorbents. The majority of installations utilize refrigeration and the ensuing discussion will be limited to this method of cooling and dehumidification.

The **selection of refrigeration** is largely

a problem of first and operating costs, with the general limitation that if the refrigerant is to be used on the store premises it should be of a type which is free from explosive or toxic hazards. The use of well water, evaporative condensers, cooling towers, and city water for condenser heat removal are determined by local conditions.

Distribution of Freon in a so-called direct expansion system is not necessarily limited to the smaller installations, as has been the general practice. In some cities there are codes which govern the quantity of refrigerant which may be used in a system of this type.

In general, water is the means of conveying heat from the air cooler to the refrigeration system. Water is frequently used in coils where there are a multiplicity of air cooling devices located at different levels. It is advisable to provide a local spray pump for cooling coils in department store application. Where air cooling can be accomplished without unusual problems incident to returning the water, the **air washer** is well applied. Failure of maintenance can cause only temporary difficulties in an air washer, whereas poor maintenance can substantially reduce the performance of coils. The washer is less subject to danger from freezing.

The problem of **coil freezing** is of increasing importance in department stores because of the practice of eliminating outside exposures, in many cases forcing the use of refrigeration at a time of the year when freezing weather can occur at short notice. Ordinary cooling coils installed with the tubes level and drained at both entering and leaving header will hold sufficient water to cause considerable damage when exposed to sub-freezing temperatures. Protection of standard coils can be accomplished by pumping out with antifreeze solution or by blowing clear with large quantities of pressure air. Neither expedient is entirely satisfactory, particularly for changeable weather. Where coils are not completely drained, the temperature control system is not adequate protection against freezing. Trouble may be encountered due to steam failure, control failure from exposure of parts of the control system to sub-freezing temperatures, and to stratification of outdoor and return air, sometimes aggravated by the operation of a preheating coil. Drainable coils are available. These coils are installed on an incline and all return bends on the lower end are connected to a drain header. Antifreeze solutions may be used if provision is made in the original design.

Where sprayed chilled water coils are used, the problem of the chilled water circuit is relatively simple. The dew point of the apparatus may be controlled by a three-way valve or by a throttling valve,

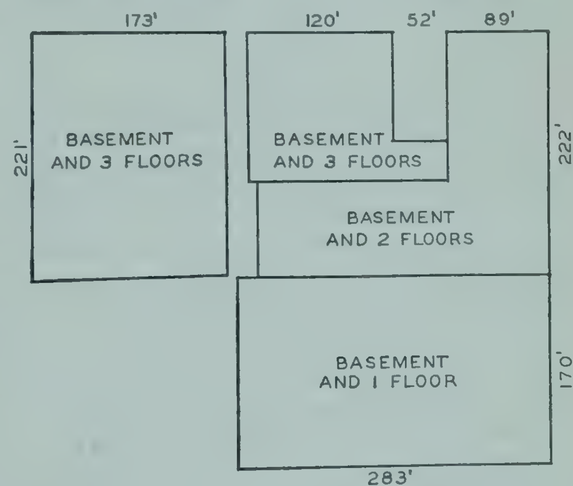


Fig. 2. Floor Plan of Gimbel Philadelphia Store. 1937 Installation.

in which case a differential governor between supply and return line will be required at one or more points of the system. In many cases, reasonable control of dewpoint can be effected by controlling the temperature of water at the refrigeration machine only. Where control is used, it can be effected either by the dew point or by the temperature of the water leaving the coil. In the design of the closed chilled water circuit, a small expansion tank is required. This should be located somewhere on the return piping and may be of either the open or closed type.

Where two or more spray-type **dehumidifiers** are used, the problem of balancing water circuits is introduced. Washers on the same level will require an equalizer pipe unless the returns are vastly oversized. Where washers are located on different levels, an open water storage tank is advisable. Each washer pan should then be provided with a weir. In some cases the

pan of the lowest washer can be used as the storage tank. Where washers are spread over large areas, return pumps may be used. A dependable arrangement is to provide **return pumps** with relatively low inlet velocities, set so that the desired water level in the washer is slightly above the top of the pump eye. The pumps may be operated continuously and will return any available water, as they will be self-priming. The method has considerable advantage over the careful balancing of automatic throttle valves. Return pumps should be sized for approximately 10 percent above the design capacity of the spray nozzles.

In department stores, dew point control of the air washer in summer is frequently effected by controlling the temperature of the chilled water circulated. The dew point seldom varies more than 2 F from the returning chilled water. Control of chilled water flow is usually not required.

Where chilled water or direct expansion coils are used, they should be provided with a liberal spray, both to protect the coils from dirt accumulation and to effect some improvement in odor level. The spray also serves for the limited winter humidification required.

In air washers for winter operation, it is advisable to have a local pump for flooding the eliminator plates. This provides some air cleaning, some reduction in odor level, and sufficient humidification. There is no reason to believe that humidities in excess of 30 percent are of any advantage in winter. The operation of the small spray pump, in lieu of the main spray pump, effects an operating saving both in power and heating cost.

The **central station system,** in which one dehumidifier serves a number of areas, lends itself most easily to the problems of changes in department store layouts, lighting, and people concentration. Where it is desired to use complete individual "units" for each department of a department store, the engineering has in the past been similar to that of the small shop with the exception that chilled water from a central plant is frequently used in lieu of direct expansion.

On occasions, the economics of space utilization and structural conditions dictate decentralization of the air treating equipment. When this equipment must be located on the selling floors, there is a relatively large loss of space. When ceiling heights are adequate, so-called units can be suspended and allow working space below, in which case good practice for maintenance indicates the desirability of a full working platform and preferably an enclosure.

Factory assembled air units are frequently used, primarily in the interest of first cost. When contemplating such units, careful consideration should be given to

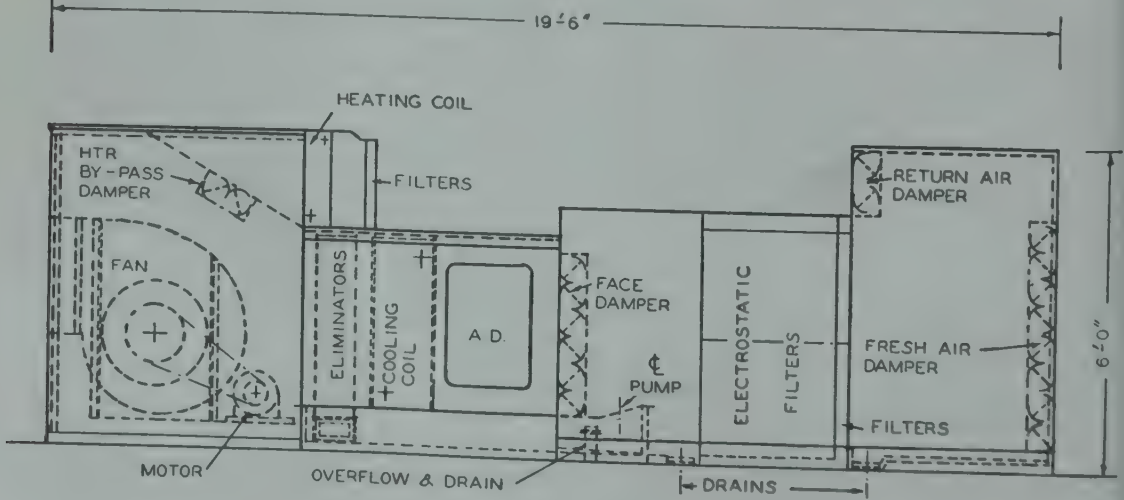


Fig. 3.

access for maintenance and repair and provision for adequate filtration, including means for the routine servicing of filters. The incorporation of electrostatic filters, with adequate provisions for their cleaning, is usually difficult and costly. It is also for note that the fans in such units often do not have as desirable characteristics as would be obtainable were there not severe space limitations.

Where decentralization appears advisable, it is possible to design the equipment to provide most of the features that would be found in central station equipment.

A shop assembled small central station unit for 13,000 cfm is shown in section in Fig. 3. The limit load fan with its motor is mounted on a frame and supported on vibration eliminators at three points. Provisions are made for spraying the cooling coil. Electrostatic filters are provided with adequate water and drainage facilities for recleaning in place.

The outdoor intake chamber and dehumidifier chambers are insulated and metal sheathed. The fan chamber is lined with sound absorbing material covered with perforated metal.

On one installation, Saks Fifth Avenue, New York, there are 31 ceiling units of this size and type, each located on an enclosed working platform and the space beneath is used for general store purposes including dressing rooms, offices, sales and stock.

Equipment Location

Sales area in a department store is obviously valuable, and apparatus encroachment on sales area should be minimized. In meeting this limitation, apparatus is frequently installed in inaccessible and cramped spaces with the hope of a super maintenance, which seldom materializes. The result is a depreciation in performance.

In designing an air conditioning system, there should be constant thought of maintenance and of necessary **access** to essential parts of the equipment. Good access does not necessarily mean large space requirement.

In general, compressors are installed in the service areas of the basement. In many cases they can readily be installed on the roof. The selection of space depends again on the economics as judged by first cost, rentable area, maintenance and operation. Where it is planned to use one or more large central dehumidifiers, it is frequently practical to install this apparatus on the roof. Such a location has the advantage of using the minimum of sales space and providing outdoor air at the best location without requiring the use of a fresh air duct to some lower floor or the admission of outdoor air at or near street level, with its consequent burden of dirt and odors. The roof location has the further advantage that the distributing ductwork decreases from top to bottom. This decrease has a rough relationship to the increasing value of floor space and the difficulties of construction. In very large projects both basement and roof locations of air washers are indicated in order to minimize the apparatus space requirements on the first and second floor.

The requirements of air distribution and area temperature control are similar to those of other structures. Where there are large expanses of glass, zoning is required. Where there is little outside exposure and practically no glass, zoning for cooling is not imperative. For heating, either zoning or supplemental radiation may be required in cold climates.

Control

The **air temperature** control problem is similar to that of other structures in the need for simple rugged controls. Temperature control in an area can be secured by bypass at zone fans, supplemented by reheat (steam or water), or by a hot and cold duct system. Volume control can be used successfully only where the ratio of the variable internal load to the peak internal sensible load is low (approximately 25 percent or less). Application of volume control beyond these limits is quite unsatisfactory. Partial saturation, whether by air washer or coil, is subject to a similar limitation.

The automatic control of **water temperature or evaporator pressure,** depending on whether water or refrigerant is used in the air cooling apparatus, is similar to most refrigerant control problems, but the variation in load caused by the condition of out-

door air may be quite large. Many of the larger department stores depend upon manual regulation of the water temperature or refrigerant pressure.

For large centrifugal machines, practical controls are available by which chilled water temperature may be automatically maintained. Automatic control is not considered advisable for the large reciprocating machines previously used. With the advent of relatively high-speed multicylinder equipment, automatic control of water temperature or refrigerant pressure can be readily obtained, and this equipment can more safely be permitted to start or stop without manual attention.

Installation Costs

The overall cost of air conditioning per net square foot of conditioned space, as of 1940, was approximately as follows:

	Median	*Avg Low*	*Avg High*
Basement	$1.25	$.75	$1.40
First floor	1.30	.75	1.55
Upper floors	1.15	.75	1.35

1950 costs showed great variation but in general were from two to three times those which prevailed in 1940.

Prices do not include additions to existing boiler plants as, in general, conditioning in department stores does not require additional boiler equipment. Where changes in steam generation are required, the cost should be added to the above figures.

The above figures include an approximate allowance for plumbing, steam connections, electric wiring, electric service, painting and decorating, and building construction and alterations; they may therefore appear higher than the originally quoted figures, which are usually limited to the trades covered by the "air conditioning" contract only.

Wide variation in unit prices is due to difference in load concentration complexities introduced by the physical layout, and normal business fluctuation. The average and high figures cover systems for year-round use. Low figures are applicable to systems providing summer cooling only. Low figures, in general, cover simple direct expansion systems using city water for condensing. High figures, in general, cover chilled water systems with cooling towers or evaporative condensers. The average and high refer to systems of better quality but do not cover costs of special and unusual conditions.

Sub-division of floors, as for sale of women's wear, increases these costs.

The distribution of total installed costs, in per cent, is roughly as follows:

Air conditioning equipment	18.5
Ducts	18
Cold water piping	7.5
Mechanical refrigeration	21
Cooling tower or evaporative condenser	10
Electric wiring, Plumbing, Steam piping, Building alterations, Painting	25
	100

Operating Costs

Operating costs of a conditioning system can be safely estimated by analyzing the individual **power requirements of each motor** on the system. In most localities the power costs can be readily obtained by analyzing and frequently by graphing the cost per kilowatt against the hours' use of the maximum demand by months. Incremental power costs may be used, because the problem is usually the determination of the additional cost of air conditioning.

Water costs can be determined from the analysis of the refrigerant load, with a liberal allowance for drift and continuous blowdown from spray apparatus and water requirement for cleaning and refilling the system.

Filter maintenance will vary greatly with the locality. If throw-away filters are to be used on outdoor air, the estimate of filter cost should be based on previous experience in the same territory.

Manufacturers' estimates may, in general, be safely followed for **loss of refrigerant,** with the exception of an allowance for major breakdown.

Labor necessary for cleaning and main-

enance is difficult to estimate because it is the usual practice to assign operation to crews who have other mechanical duties. An analysis of the problem in the specific store is the safest procedure.

Some manufacturers are prepared to assume complete maintenance, including oiling, cleaning, filter maintenance, and Freon; excluding only power, water, and the labor to start and stop the equipment. For small and moderate-size installations, this plan merits consideration.

Maintenance by outside contract usually does not meet with favor in large stores when an engineering force is required for reasons other than air conditioning.

If you searched this chapter for something which was not found in it, please let the editors know.

62. VARIETY CHAIN STORES

"LIMITED Price Variety Chain Stores" is such a mouthful that most people have continued to call them "Five and Tens"; this in spite of the fact that five dollars is closer to their present price limit than is ten cents.

The extent of the field for air conditioning in Variety Chain Stores may be judged from the following figures, based on surveys made by the publication "Chain Store Age." At the end of 1948 there were 842 chains with three or more stores, representing a total of 10,253 stores. It was estimated that 11% of these were air conditioned up to the end of 1941. No comparable figure is available as of this date, however it is estimated that in each of the years 1947 and 1948 about 150 million was spent for modernization, of which about 6.8 million was devoted to air conditioning. (These figures include General Merchandise Chains, as well as Variety Chains, the difference being that the latter derive the bulk of their income from items costing less than \$5.00.) The percent of stores remodelled fell from 9.3 in 1947 to 7.2 in 1948, while the number of new stores opened rose from 2% to 4% of the existing totals. The greatest air conditioning activity in this field is still in the existing stores.

From the air conditioning engineer's standpoint they are, in general, stores that are too big for a package unit and too small for a centrifugal machine. The tailor-made direct-expansion Freon job is the characteristic installation, and the tonnage is usually somewhere between 30 and 200. While self-contained air conditioning units are finding greater application than formerly in these stores, they are not typical, and their application is considered in another chapter (see Chapter 63). The sales area is, in most cases, between 6,000 and 35,000 sq ft.

H. P. Waechter, Author Chapter 62. Born 4/5/01 in New York, N.Y. Educated at Columbia University, AB, 1922; ME, 1924. Formerly, Ventilation draftsman, engineer and squad leader, N.Y. Edison Company; sales promotion work, Celotex Company; estimator, engineer, and field supervisor, York Corporation, Brooklyn, N.Y.; in charge of air conditioning work, W. T. Grant Company.
Author Chapter 57, 1946 Applications Volume, ASRE Data Books.
Member, Amer. Soc. of Refrig. Engineers and Amer. Soc. of Heating and Vent. Engineers.
At present, Chief Engineer, United Merchants Laboratories, New York, N.Y.

The Space to be Conditioned

These stores, in the great majority of cases, use the street floor and the basement for sales areas, or else the first floor only. They are usually either rectangular or "L" shaped. They generally have, besides the sales spaces, at least one additional floor, which is used for stock. This may be in the basement or on an upper floor, and it is often in this area that space is found for the air conditioning equipment.

Lighting and people constitute the principal **inside heat loads.** The expected concentration of people will usually be established by the merchandising management rather than by the designing engineer. A survey made in one chain showed that the people concentration will average two-thirds as great in the basement as on the first floor. As a result of the survey, a schedule, which was fairly closely followed, was set up as follows: In medium-sized stores (less than \$750,000 annual sales) the first floor was figured at 26 sq ft per person, and the basement at 39. For stores larger than that, these figures were 22 and 33 respectively. This will not, of course, hold for all chains. In some stores concentrations as high as 15 sq ft per person on the first floor and 20 sq ft in the basement are used. The maximum concentration of people is usually considered to take place at 3 p.m.

The lighting load, where incandescent lighting is used, will run around 4 to 5 watts per sq ft in average remodelled stores, and around 6 watts or more in deluxe units. Where fluorescent ceiling light-

ing is used, the wattage will be only 60 to 75 percent as much, depending on how much incandescent counter and spot lighting is used. Care must be taken that cool air is not discharged against the fluorescent tubes, as this greatly lowers their output.

Various ventilation methods have been proposed for reducing the heat load contributed by the lighting wattage, but they have not come into any considerable use in stores of this type. There is usually a lamp display department where a still higher concentration of lighting exists, and additional air should be supplied to it to take care of this load.

A sizeable lunch counter is usually found, introducing heat and moisture loads from steamers, griddles, toasters, etc. This may be a long counter running the length of a side wall, or it may occupy a rectangular area. A store with 15,000 sq ft of sales area may have from 40 to 100 stools. Knowing what equipment there is, the heat output can be obtained from tables readily available.

Sometimes kitchens are provided outside the sales area but communicating with them by counter openings. In that case the exhaust provided for hoods plus kitchen ventilation will be considerably greater, and an outside air supply system should be provided to almost, but not quite, balance the exhaust.

Table 1 lists the cooking equipment used in a 92-stool straight counter, installed in a store having 26,000 sq ft of sales area, with a separate kitchen.

Since the population peak is assumed to take place at 3 p.m., it does not coincide with the lunch counter peak, and a load factor of 50 percent can be applied to the above figure, providing it is a straight lunch counter. If it is a segregated lunchroom area, it must be figured for the peak, and zone control provided in the supply duct to it. The load may be considered to be half sensible and half latent.

Table 1. Typical Heat Load from Cooking Equipment of 92-Stool Lunch Counter

Item	Output, Btu per hr	Vented hood	Btu per hr to store
3 6-ft steam tables	13,500	Yes	6,750
4 4-burner stoves for coffee	80,000	Yes	40,000
1 4-burner gas stove	20,000	Yes	10,000
1 Griddle	28,000	Yes	14,000
1 Urn	5,000	No	5,000
3 Thermotainers	10,200	No	10,200
3 Toaster shelves	28,050	No	28,050
Peak Btu per hr to store			114,000

Show windows generally have backs of plywood panels, and heat is transmitted through these from the intensely illuminated show window space. This transmission may be figured on the basis of the show window temperature being 30 F above outside design temperature. The most modern stores are eliminating show window backs to some extent. Awnings are commonly provided over windows exposed to the afternoon sun.

There is seldom a roof directly over the sales area, but where there is, the installation of roof insulation is an economy. Roof skylights are preferably eliminated entirely.

An employees' rest room and an office are often located on the stock room floor, and these should have a supply of cool air, usually without recirculation. The supply to these rooms will run around 2 cfm per sq ft, and the supply quantity is usually under hand damper control by the occupants. Radiators should be provided for heating these spaces in winter.

Outside air required for **ventilation** is usually supplied at the rate of 10 cfm per person, based on the design population. At most times the population will be less than this, so each person will normally get more than 10 cfm. Only two complaints of odors were received from numerous systems designed on this basis—in one case cooking odors from an unvented griddle were at fault, and in the other the manager had installed a tame monkey near the foot of the main stairway as an added attraction!

The amount of outside air corresponding to 10 cfm per person is usually enough to compensate for the loss through lunch counter hoods, the unreturned supply to office and rest room, and still maintain a slight pressure at the doors, providing these are kept closed. If the doors are kept open,

additional outside air must usually be used, since each double door is figured at about 2,000 cfm. If doors are normally closed, 20 to 25 percent of that amount is sufficient.

Outside design conditions for all parts of the country can be determined by the designer from the considerable volume of published data that exists. Inside design conditions are based on physiological reactions, and the standard of 80 F and 50 percent rh during maximum outside conditions, is generally accepted. In a few locations, as in the Southwest, a higher inside condition is preferred, and this may be taken care of by thermostat adjustment.

In chain stores, as in most comfort applications, a wise policy is "don't overcool." Stores of this type are on the border line between "short occupancy" (less than 45 min) and "long occupancy." It is safer to follow conditions recommended for "short occupancy," with the exception that, if there is a separate lunch counter section, it may safely be kept a degree or two cooler.

Variety chain stores, which are ordinarily located in the highest rent section of a city's business district, sometimes occupy surprisingly antiquated and unsubstantial buildings. Often a store location is selected by combining several buildings and remodelling the premises. Stores of this nature present a most difficult problem to the air conditioning engineer. Upper floors are often not strong enough to support the weight of heavy equipment, ducts are difficult to fit in, especially where ceilings and columns do not line up, basement ceilings are often very low.

The Air Conditioning System

The sensible heat ratio for these systems usually lies between 70 and 80 percent, requiring an apparatus dew point of 52 to 56 F. Supply-air temperatures, from direct expansion coils, are usually 55 to 60 F.

There is considerable variation in the sq ft per ton; however, **Table 2,** worked out for average conditions, will give an indication of what may be expected.

The cfm required per sq ft is in the neighborhood of 1.8 for the first floor and 1.2 for the basement. This is on the basis of no bypass air. It is, however, good practice to bypass enough air to the basement, or other low headroom spaces, so the entering temperature is not less than 65 F. This will raise the total supply air to the basement to about 1.7 cfm per sq ft.

Table 2

	Basement		First floor	
Outside wb	75	78	75	78
Sq ft per ton	290	250	200	170

Refrigeration system. It is customary to provide a single refrigeration system for a store, consisting of one compressor, or several (usually two) in parallel; condensing means, consisting most frequently of an evaporative condenser, or two in parallel, though sometimes using, instead, a shell-and-tube condenser supplied with city water, cooling tower water, or well water; a low side, consisting usually of finned direct expansion coils with thermostatic expansion valves. Such coils are sometimes provided with a recirculated water spray, which flushes the coils, and provides a degree of evaporative cooling in intermediate seasons. Such a spray may also be used for winter humidification, although the need for this is not generally accepted for this type of installation.

Several different arrangements of the **low side** are possible, and the judgment of the designer, as influenced by the space available for equipment rooms and duct risers, comes into play here. Thus there may be a single stack of cooling coils with a single fan, located either in the basement or on an upper floor; there may be a single stack with a partition plate and two fans, one for each floor; there may be a stack of coils and a fan in the basement for the basement system, and similar equipment on the second floor supplying the main floor. The existence of local codes must be investigated, since, in some cases, they limit the running of Freon lines between floors.

Factory-built **evaporative condensers** are used up to the limit of the capacity in which they are made, and larger capacities may be provided for by using built-up units with separate blowers. The factory-built units are often located in the open

on the roof, and it is frequently necessary, in old, wood-joist buildings, to provide diagonal steel beams across a rear corner of the building, so the weight will be carried on the brick walls. Before resorting to this design, the condition of the bricks and mortar should be inspected to assure safety, and it may sometimes be necessary to find room in the basement for this equipment.

The great majority of **compressors** are of the multi-cylinder, high-speed, reciprocating, Freon-12 type. Probably the commonest sizes are 50, 60 and 75 hp, either single or in parallel. Relatively few installations, in the larger stores, have centrifugal refrigerating machines, and in such systems spray dehumidifiers are sometimes used, instead of finned coils. Several hermetically-sealed centrifugal water cooling units have also been used in 70 and 100 ton capacities.

The approximate area that must be allowed for the air conditioning machinery room, where all the equipment except the evaporative condensers is in one room, will be around 6 to 8 sq ft per ton. Of all the possible **equipment arrangements,** most fall into five general classes, each of which is represented by numerous installations:

1. All equipment in basement machine room
2. All equipment in basement machine room except evaporative condensers
3. Compressors and basement low side in basement equipment room; other equipment above first floor
4. Compressor in basement equipment room; other equipment above first floor
5. All equipment above first floor.

Arrangement No. 5 is usually used in a new store building where the air conditioning system is laid out as an integral part of the design. This is done because basement space is considerably more valuable than upper story space. Where the system is fitted into an existing store building, which represents the great majority of present installations, the design is most likely to call for one of the first four.

Electrical factors. The selection of compressor **motors** and **starters** should be given special consideration. It is advisable to find out from the power company in the locality what limitations they will impose on the starting inrush. Large cities usually limit the increments of currents per unit time interval. Smaller cities usually limit the maximum momentary current. Squirrel-cage motors started across the line are, in most cases, permitted up to 30 hp. Above that a reduced voltage step started with a normal torque squirrel-cage motor will take care of the former limitation, while for the latter a high torque double-squirrel-cage motor with a step starter can be used, provided the torque is enough to start the compressor under reduced voltage. Either manual or automatic unloading of the compressor greatly reduces the torque needed. Slipring motors may have to be used where the starting limitation is particularly severe.

With two compressors in parallel a time delay relay can be used to advantage by preventing the second compressor from starting until the first compressor has come up to speed. This relay can be connected into the starter holding coil circuit of the second compressor. An alternating relay is desirable to keep the wear on the compressors uniform.

Interlocks should be provided so the compressors cannot run unless the main fan and the evaporative condensers are first running. Remote push buttons with pilot lights are desirable for fans and evaporative condensers located elsewhere in the building.

Since the compressors are often installed in a confined space, such as a sidewalk vault the need for positive machine room ventilation should not be overlooked. Thus, compressor motors totalling 100 hp, with an assumed efficiency of 85 percent, will require about 3,500 cfm to limit the temperature rise to 10 degrees above the temperature of the ventilating air. The ventilating blower may be wired to start simultaneously with the compressors.

Well water. In many cities where air conditioned variety chain stores exist, it is possible to secure **well water** in adequate quantity and at reasonable depth. If water at 54 F or less can be had in a quantity of about three gallons per ton, the whole refrigeration effect can be obtained from it

The water may be used in a spray dehumidifier or in surface coils, preferably of the cleanable type. Where well water between 55 and 65 F is available, it can be used for precooling and condensing.

Before a well is decided on, local conditions must be carefully investigated, to make sure of the reliability of the supply and of the continuance of the prevailing temperature. Where many wells are driven in close proximity, there is danger of the water level falling, leaving the shallower wells dry. Where water is required to be returned to the ground by means of return wells, there is a tendency for the temperature to rise as the summer progresses. Possible undesirable chemical characteristics of the water should be investigated.

Sources of information on this subject include the local Department of Water Supply, the various deep well pump manufacturers, local well-drilling contractors, and the manager of the local chain store (if it is an existing store). Various U. S. Department of Commerce bulletins also throw light on the water situation in all cities of over 20,000 population. When local well contractors are unwilling to guarantee water in the specified amount and temperature, at a fixed cost, the well water situation should be viewed with suspicion. (See p. 275 basic vol., 5th ed.)

Where city water is relatively cold, plentiful, and cheap, it may be considered for condensing purposes. There are, however, few such locations, and in most cities where city water is permitted for condensing there exists the possibility that the supply may be cut off during a hot, dry spell, leaving the store without air conditioning just when it is needed most. The matter of city sewer capacity should be investigated before depending on it to carry away the water. Some cities even levy a sewer tax on condenser water discharged into the sewers.

Automatic control. Countless variations and modifications of automatic control are possible, and in use, in chain store systems. Most designers of such installations agree that the systems should be relatively foolproof, since they are so often operated by unskilled help. While extreme complexity should be avoided, the control should be comprehensive enough to prevent such possible blunders as having steam on the heating coils while the refrigeration is on, or running on a hot day with the outside air damper wide open, or leaving outside air dampers open on a cold night.

Since no control system can be said to be "typical," the following description is confined to an arrangement which has been successfully used, and which was designed with the special requirements in mind of an existing chain store in which an air conditioning system was installed. This specific example is based on a store with first floor and basement sales areas, each with a separate surface-type air conditioner, and having a common refrigerant circuit including a 60-hp compressor and evaporative condenser. (See **Fig. 1.**)

Safety controls include the above mentioned electrical interlocks, hand-reset high-pressure cutout, and Underwriters thermostats wired into the fan starter circuits.

A room thermostat is provided for each floor (these should be used rather than return air thermostats if the return grilles are near, or in, the ceiling). Each thermostat is duplex, consisting of two instruments in one case, one for winter and one for summer. A summer-winter switch determines which will control, the summer position being used for refrigeration, and the winter at all other times. The winter thermostat will normally be set for 70 or 72 F, while the summer thermostat will be set at various times between 75 and 80 F. Store managers like to exercise control over the summer store temperature, as dictated largely by the overheard reactions of customers.

The summer thermostat controls automatic cooling coil face and bypass dampers, which have a pilot positioning device and a stop to prevent reduction of the air quantity through the coil below about 30 percent of normal. As the suction pressure falls due to the decreased load, a suction pressure switch actuates the compressor capacity control, to about 50 percent. The final step of stopping the compressor is done manually.

There are two automatically operated outside air dampers for each system, one

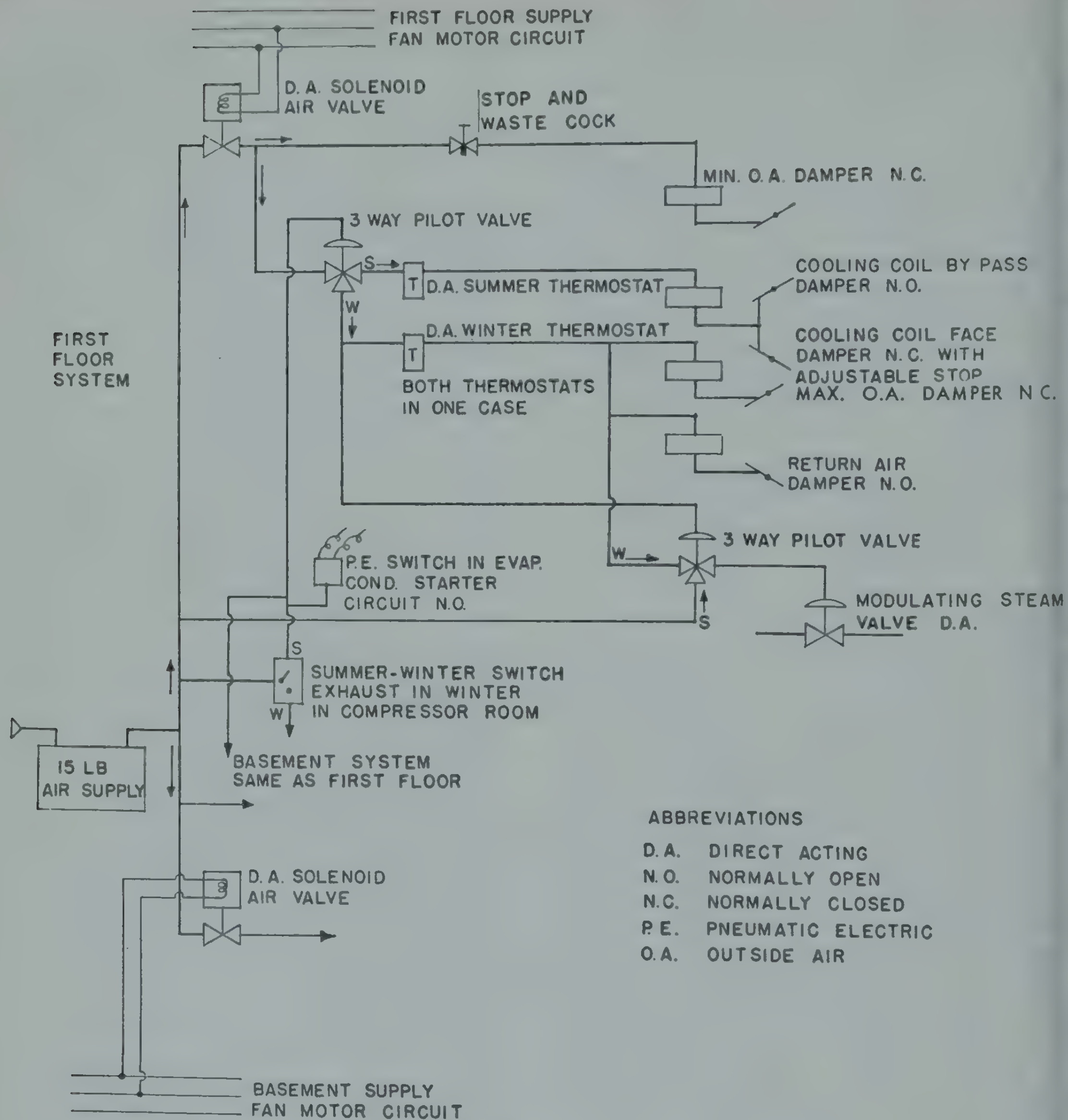


Fig. 1. Typical Pneumatic Control Diagram for Main Floor and Basement Systems.

sized for the minimum ventilation requirements, and the other for the remainder of the fan capacity. The smaller ventilation damper has a switch so that the outside air can be shut off completely for warming up the store on cold mornings. These dampers automatically open wide as soon as their fans are started. The large outside air dampers are controlled by their respective winter thermostats so that in the intermediate seasons 100 percent outside air may be taken. When the fans stop, all outside air dampers are automatically closed. Each winter thermostat also controls a modulating steam valve, which starts to open after the maximum outside air damper has closed. The outside air intake should be so arranged to prevent bypassing of air around the cooling coils.

The functions of the summer-winter switch may be summarized as follows:

In Summer Position:

1. Puts the summer thermostats in control of face and bypass dampers
2. Holds steam valves closed
3. Holds maximum outside air dampers closed and return air dampers open

4. Starts evaporative condenser and permits compressor to run.

In Winter Position:

1. Puts the winter thermostats in control of steam valves and maximum outside air and return air dampers.
2. Stops evaporative condenser and prevents compressor from running.

No provision is here made for winter humidification; however, sprays controlled by a humidistat are sometimes included.

Three-wire fan motor push-buttons serve as no-voltage cutouts, and prevent all the motors from coming on when current is resumed after an interruption.

Air distribution. In chain stores, as in other applications, the satisfaction realized from an air conditioning installation depends largely on the air distribution. It is not so critical, however, as in a restaurant or a theatre, since people are continually moving about (except at the lunch counter) and are not so much affected by slight local drafts. Supply ducts are equipped with either ceiling-type or side-wall-type outlets. Ceiling outlets are used where the supply ducts are installed above a flush hung ceiling, while for the more common case of ducts installed below the ceiling line, side-wall outlets are the more prevalent. Most **supply-duct arrangements** will fall into one of the five types shown in **Figs. 2 to 6,** or combinations of them.

The design shown in Fig. 2 is probably the commonest, requiring a minimum of furring, and being best suited to low ceilings. The ducts are usually flattened out in a vertical direction, so that the face of the plaster furring is flush with the cornice at

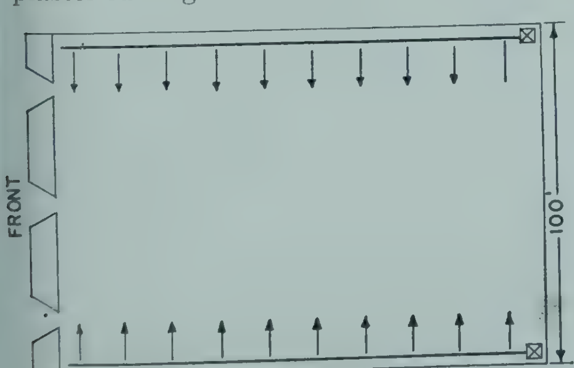


Fig. 2. Side Wall Air Distribution.

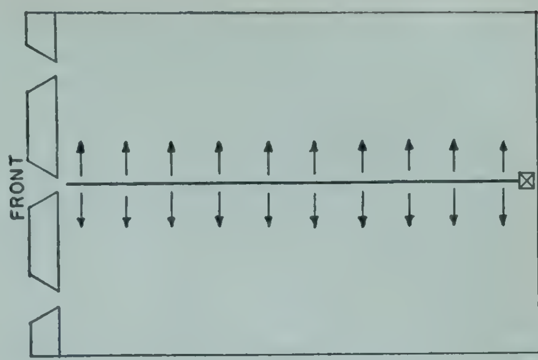


Fig. 3. Center Duct Lateral Distribution.

the top of the shelving. The top of this cornice is usually 6 ft 10 in. or 7 ft above the floor, and projects about 14 in. from the wall. The duct must therefore be about 10 in. wide to fit into this available space, and the plaster will run from the top of the

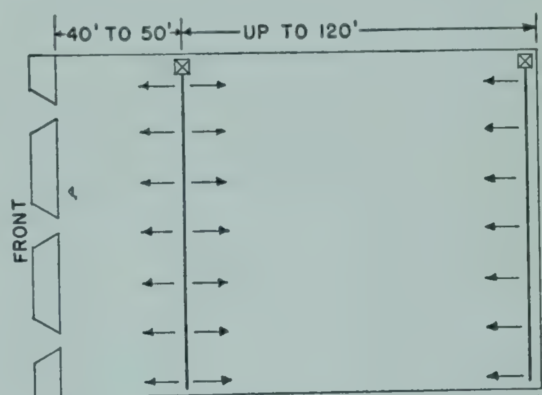


Fig. 4. Transverse Duct Distribution.

shelving to the ceiling. In the basement the available head room often is not great enough to permit the duct width to be limited to 10 in. The plaster line will then project beyond the shelving cornice, but this should be avoided wherever possible, as it creates an undesirable shadow.

Fig. 3 can be used only where the ceiling is high. **Fig. 4** often fits in well where there are beam drops running across the store. **Fig. 5** takes advantage of the space over the show windows to conceal a duct, thus decreasing the size of the other ducts exposed in the store. The duct in the space over the show windows must be insulated. To assure proper cooling of the front area with this design, a supply grille over each entrance door is usually provided, blowing

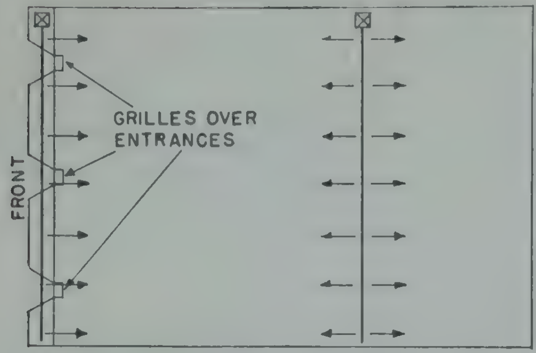


Fig. 5. Transverse Duct Distribution.

downward at a velocity not exceeding 300 ft per min. In cold climates a heating coil can be located in these branches for winter use. Where such outlets are not installed as part of the air conditioning system, a unit heater with a short duct to a similarly located grille is usually provided for each entrance.

The arrangement in **Fig. 6** may be used either with ducts run above a hung ceiling or with ducts below the ceiling. Fairly high head-room is required in the latter case. Smudged ceiling areas around the outlets sometimes result, but the air distribution is generally excellent. The cost is often somewhat higher than the other methods. A modification of this arrangement which is sometimes resorted to, for the sake of appearance in the store, is to run the ducts at the second floor ceiling with individual drops to outlets at the first floor ceiling. This, of course, can only be done when the second floor is available as a stock room. Side-wall outlets, also, are sometimes used in combination with individual drops from the second floor ceiling.

A general rule on air throw from side-wall grilles is not to attempt to blow more than three times the ceiling height; however, there are enough cases where this rule has been exceeded to make it of doubtful value. Where grilles are located close under a smooth ceiling, exceptionally long **throws** have been achieved, although such grille locations usually cause a smudged ceiling in front of each grille. The author recommends limiting throws on the first floor to 60 ft, with a maximum of 1,400 cfm per grille, and in the basement, 40 ft, with not more than 800 cfm per grille.

Grille velocities should be limited to about 1,000 ft per min to avoid excessive noise. Duct velocities starting around 1,600 ft per min are common.

The first bay of the main floor, just inside the entrance doors, is the one most likely to be insufficiently cooled, partly because the additional load due to entrance doors and show-window backs is often not provided for, and partly because the grilles supplying this space are often at the end of the duct run, and thus do not always deliver what they are designed for.

In order to secure air delivery perpendicular to the duct, vertical adjustable straightening vanes are desirable. When these are used in conjunction with adjustable horizontal grille vanes, the maximum of flexibility is obtained for adjustment in the field.

Ducts running below the ceiling are, in most cases, enclosed in plaster applied on metal lath, held by furring strips. This procedure is rather expensive, particularly when an existing plaster cornice must be removed and a new one to match it installed in front of the duct. In some cases, especially in a basement, the duct enclosure is made of hard board or plywood nailed to wooden strips, with puttied joints. This enclosure cannot be used in a fire-proof building, but it is cheap, and the appearance is fairly good.

Where the system is installed in an old store having metal ceilings and cornices, the **furring** is sometimes omitted entirely as a measure of economy. The appearance of such an installation, with conventional duct construction, leaves much to be de-

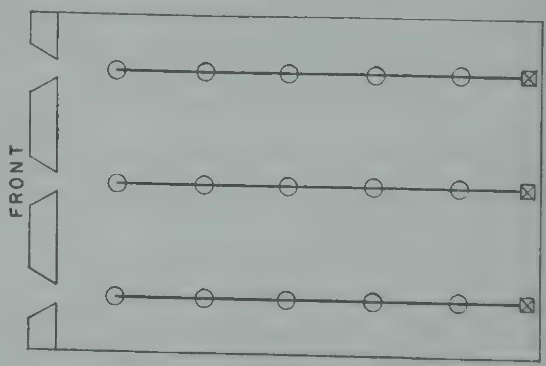


Fig. 6. Air Distribution from Ceiling Diffusers.

sired. A method of duct construction has been developed in which there are no external standing seams or exposed hangers. A special seam filler is used to make the seams invisible. When the duct is painted to match the ceiling, the appearance is rather good. Grilles must be set flush in the duct, without the usual 3 or 4-in. long throats which contain the straightening vanes. To compensate for this, the duct should be made slightly larger.

The location of **return air grilles** is of minor importance, except that they should not be located near a door or an elevator shaft, where the suction would tend to pull air into the space from outside. These grilles are, of necessity, large, and fitting them into an elaborate decorative scheme often presents a problem to the designer.

It is common practice to locate a separate return grille on each of the sales floors; however, in a few cases the basement grille has been omitted, and the first floor grille has been increased and located directly over the main stair to the basement. The stair opening is thus used as the means for returning the basement air.

The constant stream of air into the grille will carry dust with it and quickly deposit a coating which is unsightly and may even obstruct the opening. Grilles should, therefore, be located, whenever possible, where they are accessible for cleaning. Where location in the first floor ceiling cannot be avoided, a grille with large openings should be used, and any ductwork visible through it should be painted flat black. Side-wall locations near the floor are seldom used, since the management is reluctant to sacrifice valuable shelving space. In a sidewall, above the shelving line, the grille may be of the type with narrow, closely-spaced vanes, tilted upward, and painted to match the wall. Sometimes the grille is given an ornamental treatment by using heavy wooden louvre blades, painted to contrast with the walls. In the basement, particularly, there is danger of a side-wall grille being obstructed by displays or signs mounted on the top of the shelving. Education of the manager on this point is the only remedy.

Return grilles under counters or display cases have been used, but such practice has the disadvantage of drawing in dirt and papers from the floor, and of creating a draft around the ankles.

Gross grille velocities of 600 to 700 ft per min and duct velocities around 1,200 ft per min are common.

Air filters. Both outside air and return air should be filtered. Every existing type of air cleaner is being used in chain stores, from electrostatic precipitators to the cheapest throw-aways. When yard goods, curtain material, etc., are sold in relatively large quantities, the dry strainer type of filter for return air appears to have an advantage over the viscous impingement type, because of the relatively large amount of lint in the air.

Regarding fire hazard from filters, there is a lack of agreement among Fire Insurance Rating Boards in various parts of the country. Some boards consider a dust-laden filter to be an unavoidable fire hazard regardless of the material of which it is made, while others impose a penalty for using certain types of filters. In selecting the type of filter to be used, it is well to check this point with the local Rating Board. The installation of sprinkler heads in the filter chamber and an Underwriters' thermostat in the discharge duct to shut off the fan is required in many localities, and is desirable in all installations for the protection afforded. A light in the filter chamber is a great convenience, and this should have a vapor-tight, marine-type globe.

Ample space should be provided for access to the filters, with generously sized access doors, because servicing filters is, at best, an unpleasant job. Each bank of filters should have a resistance gage. To reduce the amount of dirt brought in from outside, air intakes near the sidewalk or roof level should be avoided if at all possible.

Economics

There are obviously numerous factors affecting the **unit costs** of an installation, and the variation will be considerable. In order to give an idea of average costs, data for a number of actual installations are presented in **Table 3.** The contracts were awarded in the post-war period, mostly in

1948, during peak prices. Costs are slightly lower at this time (1949).

These figures show a lack of consistency which is to be expected in view of the many variables involved.

The price per ton figures are about 80% higher than average pre-war figures, while the cost per square foot is more than double. This seems to indicate a trend toward more liberal capacity per square foot.

For a fairly typical 80 ton job, on one floor, the total cost was broken down as follows:

	Percent
Refrigeration cycle	62
Sheet iron, grilles, filters	28
Fans and motors	6.5
Automatic Controls	2.9
Heating coils and connections	6

In addition to the amount of the air conditioning contract, there is always additional cost incurred, in an existing store, for such items as plastering ducts, cutting and patching, machine room enclosure, electrical wiring up to main disconnect switch, steel beams to support evaporative condensers on roof. The total cost of such items will be anywhere from 15 to 50 percent of the air conditioning contract.

Electrical consumption is the biggest factor in **operating cost.** Based on an average power rate of 2.5 cents per kw hr (including demand charge) annual electrical costs could be about $28 per ton. This includes evaporative condensers, and winter operation of fans, and is based on a five month cooling period. In this connection it may be noted that two exceptionally busy periods, namely Christmas and Easter, are not in the normal cooling period in the northern half of the country. Compressors should, however, be ready for operation, and not pumped down, during both of these. Refrigeration can then be used, should the weather not be cold enough to produce proper conditions with outside air. Refrigeration should not be used unless really necessary, since the demand charge will often make the cost of operation for a brief period rather high.

The cost of water, where an evaporative condenser or cooling tower is used will average about $1 per ton per year. The amount of steam chargeable against air conditioning is debatable, but assuming ventilation air heated to room temperature, in a climate where design temperature is zero, the cost will be about $2 per ton per year.

Where an operating engineer is employed, his salary will be an appreciable part of the operating cost. He will usually be required to do miscellaneous electrical work, build displays, etc. About $12 cr $15 per year per ton will be chargeable against air conditioning on a 150-ton system. Where a stock man operates the system, devoting about one-fifth of his time

Table 3. 1949 Cost Data on Variety Chain Store Installations

No.	Outside Design DB WB	Floors	Conditioned Area	Condensing Means	Tons	Price	Price per Ton	Price per sq ft
1	100 80	1st	5,450	Evap. Cond.	33.7	$13,511	$400	$2.50
2	95 78	1st	8,800	Evap. Cond.	48	17,454	365	1.99
3	95 78	1st	12,800	Evap. Cond.	66	28,610	435	2.24
4	95 78	1st	17,400	Cooling Tower	123	46,190	375	2.69
5	95 75	1st	22,400	Evap. Cond.	140	70,000	500	3.12
6	95 78	1st and Base't.	17,100	Evap. Cond.	75	47,600	635	2.78
7	100 78	1st, 2nd and Base't.	25,510	Cooling Tower	185	76,730	415	3.00
8	93 75	1st and Base't.	33,578	Cooling Tower	169	73,835	437	2.20
						Average	$445	$2.57

Fig. 7. J. J. Newberry Company, Cincinnati, Ohio.

to it, about $6 per ton per year is chargeable to the system, based on a 75-ton system. Local code requirements determine the grade of operator in many places.

Where a periodic maintenance contract is used (see "Maintenance," p. 676) average cost will be about $9.80 per ton per year, and the chargeable time of the maintenance man may be reduced to about $4 per ton.

In addition to the more or less calculable costs of operating an air conditioning system—costs such as electricity, water, steam, and operator's salary—there are costs of which the magnitude can be learned only from experience. These include Freon replacements, repairs, service calls and air filters. Experience indicates a figure of $7 per ton per year for these items.

These figures should not be considered as the expected figures for any one store, as many stores vary considerably from the average. They are simply an average that may be expected from a group of stores.

Fixed charges and depreciation may be taken at about 15%, or about $67 per ton per year. The total of the various cost figures listed above thus becomes about $121 per ton per year, or about $.60 per sq ft per year.

The value of air conditioning is often most readily reflected in the loss of business suffered by an unconditioned store, in competition with conditioned stores. One survey showed that a loss of from 3 to 7 percent occurred during the summer and was not regained in the autumn and winter. The same survey indicated a gain in luncheonette business of 15 to 20 percent, directly traceable to the installation of air conditioning.

The factors considered by chain store management, in deciding which of their

existing stores to condition, are listed below. The order of their importance will vary with different chains.

1. Extent of air conditioning by local competitors
2. Coordination with plans for general remodeling of store
3. Climate
4. Effectiveness of existing ventilating system
5. Opportunity for increasing profits by installing air conditioning before competitors do
6. Length of lease, burden on store payroll, etc.

Operation and Maintenance

Stores of this type are faced with the problem of turning over a complicated and expensive apparatus to a store manager who usually hasn't the slightest understanding of it. The obvious solution would be for each store to hire a competent operating engineer to run and maintain the system. In the more elaborate stores this is usually done; however, in smaller stores the cost would be hard to justify. In most of these stores the manager looks over his available manpower and designates the most likely individual for these additional duties. Usually this is a stock man or porter.

It is good practice to require the contractor to submit a log, taken on a prescribed form, for a period of one week. This is useful not only to demonstrate the performance of the system and permit final adjustments to be made, but also to afford an opportunity for the designated operator to be instructed in operation and maintenance. In addition, a set of clearly written instructions should be furnished, describing the operation at each season, and listing what must be done each day, each week, each month, and at seasonal change-overs.

One of the hardest things, under such an operating setup, is to persuade the store manager that he must allow the operator enough free time from his other duties to carry out these instructions. As one store manager remarked, "We don't even have time enough to do the things we *have* to do!"

Some chains have attempted to solve this problem by having their own travelling maintenance men, so that the operator only has to start and stop the system. Other chains have entered into maintenance contracts with local contractors, some of which cover all necessary service calls, repair work, parts, and Freon, whereas others cover only a specified number of service calls, with additional charges for everything beyond. Still other chains leave it up to their managers to decide how to handle the maintenance. In the latter case, their very human tendency is to rely on the stock man operator, which is the cheapest method, and often leads to the need for major repairs later.

The sources of difficulty most frequently encountered in these systems are probably as follows:

1. Freon loss
2. Filter and V-belt replacements
3. Thermostatic expansion valve troubles
4. Electric motor troubles
5. Troubles produced in the evaporative condenser by the nature of the water
6. Dirt on cooling coils.

Item 5 can be guarded against by having a sample of the water analyzed to determine the need for water treatment. The formation of scale and the growth of algae are the main things to guard against. Various companies specialize in water testing and treatment on a national scale, and are equipped to make recommendations, furnish the material, and make periodic checks on the efficacy of the treatment.

In some chains the operator of each system is required to keep a simple daily log, which is sent to the main office and is used to check on the results obtained, and as an indication whether the system is being properly operated and maintained. The mere act of keeping such a log is likely to make the operator give more thought to his air conditioning duties than, perhaps, he otherwise would.

If you searched this chapter for something which was not found in it, please let the editors know.

63. SMALL STORES

ONE of the largest fields for modern air conditioning equipment is represented by the group of merchandise shops and small stores which endeavor to offer their customers a little more in service and satisfaction than the average. This market for air conditioning is easily reached by the conventional field sales organizations, and it uses the sizes and types of air conditioning equipment which are produced in the greatest quantity. Since this market for air conditioning is so accessible, it also is most easily oversold, under-engineered, and underpriced, and can be unsatisfactory to both the customer and the seller of equipment unless both have a knowledge of the economics involved.

When the average small store buys air conditioning it invests an amount of capital which is ordinarily greater in proportion than that required for the purchase of larger installations, and the owner is usually proportionately concerned regarding his contemplated investment. It is possible to analyze each situation for the purchaser so that he can pretty well determine just what the **advantages** are to be. If he is to install air conditioning, it should be for the purpose of increasing his profit possibilities. Among the factors to consider are increased store patronage, tendency of customers to remain within the store for a longer period, preservation of merchandise and store cleanliness, and the general impression of high business standards associated with air conditioning in the mind of the public.

Offsetting the obvious advantages of air conditioning to a store owner are the **cost factors** such as initial investment, operating cost, depreciation of equipment, and possible cost of moving or selling equipment if premises are leased rather than owned.

This class of installation can and should be handled with **standard equipment** whenever possible for the mutual advantage of both the customer and the seller, with consideration for ease of installation, ease of rearrangement, ease of maintenance and resale value. Meeting these requirements is made easier by the fact that performance of these installations is based almost entirely on comfort requirements only, effective temperature being the main consideration. Only occasionally is it necessary to consider the product handled by the store in determining the temperature or humidity desired. Appearance of the completed installation is most important to the store owner, and much thought should be given to each installation in the matter of application. Type of building construction, space available, interior architectural treatment, air distribution, ventilation and noise level are items which must be considered and properly handled in a successful installation.

Most jobs should be considered from a year-round standpoint, as this method will generally reflect economies in initial cost of heating and cooling the premises and year-round benefits of store cleanliness, ventilation and automatic operation. The question of whether or not the premises are owned, and the terms of the leases, are points which must always be considered in determining what refinements the job should include.

Since all manufacturers now have equipment specifically intended for this market, there is a wealth of arrangements for the purchaser to consider. Equipment based on

LEON L. KUEMPEL, Author Chapter 63. Born 1/13/06 in Milwaukee, Wisconsin. Educated at University of Minnesota, ME, 1929. Formerly held engineering and sales positions with Minneapolis-Honeywell and Delco-Frigidaire; established Kuempel Engineering Co. of Cincinnati; pioneered special air conditioning applications in commercial and industrial fields, and later in vehicle and automotive field.

Author of "Motor Coach Air Conditioning" in *Refrig. Eng.*, August, 1949; Chapter 58, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engineers; ASHVE; NSPE; SAE.

At present, President of The Kuempel Company and Chief Engineer of Keco Industries, Inc., Cincinnati, Ohio.

refrigeration is predominantly favored, although in certain localities refrigeration is unnecessary due to the availability of cold water, while in other localities the prevailing low wet bulb temperatures permit the use of evaporative cooling. However, refrigeration equipment is the only universally applicable means available for providing summer cooling.

The refrigeration equipment is largely based on the use of electrically driven reciprocating compressors although there has been an increase in use of gas equipment of the absorption type. Unit adsorption dehumidifiers are also used, either with water after cooling coils or with refrigeration to secure sensible cooling. The small store market has encouraged the manufacture of self-contained units of all types, ranging up to 30-ton capacity, and shipped complete from the factory ready for utility and duct connections. Fig. 2 shows a typical 3 hp self contained store type unit, and Fig. 3 illustrates a typical 15 hp central type self contained unit. Water-cooled condensers are common, but most makes are available with evaporative condenser as an accessory or included in the unit. Ordinarily, units up to 5-ton capacity are produced with built-in grilles for air distribution directly from the unit, and only the larger units are specifically intended for use with duct systems. Many jobs cannot be handled by self-contained equipment and require the older but thoroughly practical built-up type of installation, due to space or architectural requirements. Fig. 4 shows a typical built-up job for year around operation, including 3 hp compressor, suspended unit, and gas-fired boiler.

Load Determination

There has been some tendency to employ short-cut methods for sizing equipment for the small store and most manufacturers have developed procedures for simplifying this essential task. It must be emphasized, however, that many of these small shops have conditions which, if not considered fully, would introduce a sufficiently large error in sizing equipment to prove embarrassing to all concerned; small jobs are also often subject to load fluctuations far greater than can be determined by first analysis of the usual data. There is an increasing tendency toward intensity of illumination, exceeding 5 watts per sq ft in some cases. There are always the open door problem, the relationship of the average occupancy to peak occupancy on sale days, and similar matters to consider. Ventilation cannot be neglected in the small store, because of the increasing tendency of the public to smoke while shopping. It is advisable to follow routine load determination methods in arriving at the size of the equipment to be installed, and to check carefully with the owner on quantities which are subject to wide fluctuation. It should be pointed out that some owners are inclined to underestimate occupancy and other factors under the mistaken assumption that this will aid in securing a better price on the installation. If important periods of large occupancy

Table 1. Typical Factors for Load Determination in Modern Stores

Kind of store	Lighting, watts per sq ft	Ventilation, minimum fresh air changes per hr	Ventilation, minimum per person, cu ft per min	Average floor area, sq ft per ton
Camera shop	3	1	6	180
Candy store	3	1	6	180
Drug store	3	2	10	150
Drug store with lunch counter	3	4	15	120
Furrier's shop	2	1	6	250
Grocery (supermarket)	1	2	10	300
Clothing store	2	1½	7½	200
Novelty store	2	1	6	220
Jewelry shop	5	1½	7½	160

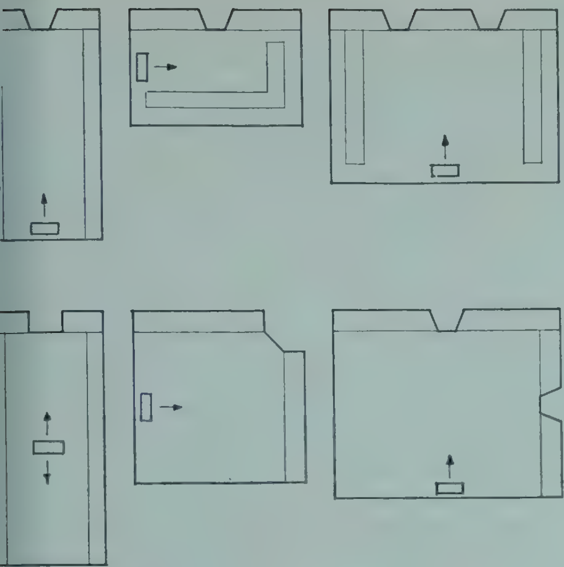


Fig. 1. Typical Small Store Plans Showing Self-Contained Unit Location.

prevail, the equipment must be sized with this in mind.

Whether the load is determined from some quick method or by a very thorough analysis, it will be well to check against similar jobs, known factors and established unit quantities. The unit quantities outlined in **Table 1** are based on average experience from typical jobs and should not be considered as applicable to any individual installation unless a careful load analysis has been followed through. Special account must be taken of any heat sources such as skylights, hot ceilings, hot floors, chimneys in year-round use, etc., because these may have a disproportionate effect on heat gain. Insulation can be used to advantage, as it is often cheaper than is the equivalent amount of cooling equipment. It is advisable to adhere to standard inside and outside conditions for the locality in question in determining the load for any comfort air conditioning job.

Many proprietors insist on **open doors.** This introduces a heat gain which can double the size of equipment needed in a small store, or can cause a serious misunderstanding between the owner and the contractor if not anticipated. If a door is to be left open the ventilation and exhaust quantities should be carefully balanced so that there is some exfiltration through the doorway to help maintain store conditions and to keep out insects and dust. Additional outside air should be introduced to compensate for this loss of barrier, a minimum of 1,000 cfm per doorway being advisable for a standard door; two or more doorways subject to cross ventilation might require 2,000 cfm each.

Equipment Selection

With the load determined, the proper size equipment can often be selected directly from the manufacturer's rating tables. In some cases, notably where extremely high lighting intensity is employed or where unusually effective ventilation is necessary, the sensible-total heat ratio will prevent the desired indoor conditions of both temperature and humidity. Reference should be made to the comfort chart and, if the equipment balances out at the same effective temperature, and conditions are acceptable to the owner, it is often advisable to use the standard unit indicated rather than to build up a special installation for the purpose. While many selections can be handled in this fashion, others will have to be determined from an analysis of all conditions, and the equipment selected accurately or designed to fit the requirements. **Factors** to be considered in determining the specific requirements are:

1. Load
   a. Design conditions
   b. Total heat gain
   c. Sensible-total ratio.
2. Economics
   a. Power cost and availability
   b. Water cost and availability
   c. Maintenance cost
   d. Initial investment.
3. Architectural considerations
   a. Appearance
   b. Space available for equipment
   c. Duct and pipe locations
   d. Access to spaces.
4. Application considerations
   a. Air distribution
   b. Noise level
   c. Structural support
   d. Accessories.

Air Distribution

Proper air distribution is essential in any job, large or small. The comfort gained by

Fig. 2. Self-Contained Air Conditioning Unit in Shoe Store.

cooling or dehumidification can be completely nullified by the discomfort caused by drafts or air stagnation. The object is to get uniform temperatures and air motion throughout the conditioned area without noticeable drafts.

Ductwork for supply and return air can be eliminated if one or more small, self-contained units can handle the load and be properly located with respect to air distribution. **Fig. 1** shows preferred locations. Note that corners and asymmetrical locations are not advised.

Ductwork is essential for handling and distributing larger quantities of air. Opinions vary as to the amount of supply air that can safely be introduced by a single grille in an ordinary room. For the small shop it is recommended that 2,000 to 2,500 cfm be the maximum amount distributed from a single outlet. Air motion should always be kept well below 50 ft per min in the occupied zone; the best jobs will be in the neighborhood of 15 to 25 ft per min.

Provided the principles of good air distribution are followed, the factors determining type of duct system and location are cost and appearance. The interior treatment of modern stores offers various methods of concealing ductwork above furred spaces, behind partitions, above display cases, or merely furred in or decorated to blend with the surroundings. Return ductwork can be quite simple and direct, since, if proper supply air distribution is employed, the return system becomes relatively unimportant. Return air grilles are best located near the floor for year-round system. Fig. 3 is a typical installation showing well located ductwork with proper supply and return air openings, and an adequately sized fresh air connection.

Supply ductwork will sweat when the

ew point of the space through which it asses is above the duct surface tempera-ure. Exposed supply ductwork in non-onditioned areas must be insulated to revent sweating. Ordinarily, supply duct-ork which is within the conditioned area nd that which is tightly furred in will not equire insulation, but the factors involved ust always be considered as in some cases onsiderable damage can be caused by con-ensation.

Ventilation

Odors, fumes, and tobacco smoke ac-umulate in air conditioned spaces in vary-ng quantities and must be kept below bjectionable concentrations by the intro-uction of sufficient outside air, or the use f air recovery or air freshening equip-nent.

Introducing the required quantity of utside air is the simplest and most direct neans of diluting the undesirable com-onents of inside air. The amount to intro-duce varies with the size of the space, the number of occupants, and the type of contamination. Refer to Table 1 for recommended quantities. The amount used should never be less than the natural infiltration quantity, and will generally run much more. The larger quantities require venting by some method, preferably by exhaust fans properly selected so a small positive pressure remains in the conditioned area.

Air should be exhausted away from sources of heat or contamination to prevent mixing with the conditioned air. When exhaust fans are used they should be installed to give double service. Good spots to consider are hot show windows, hot attics, wash rooms and cooking grilles.

Advantage can be taken of 100 percent outside air during periods when this course is beneficial, and it is well to have the outside air ductwork sized for this purpose. When this is done, it is necessary to provide sufficient relief area for the volume handled.

Very small installations can often omit

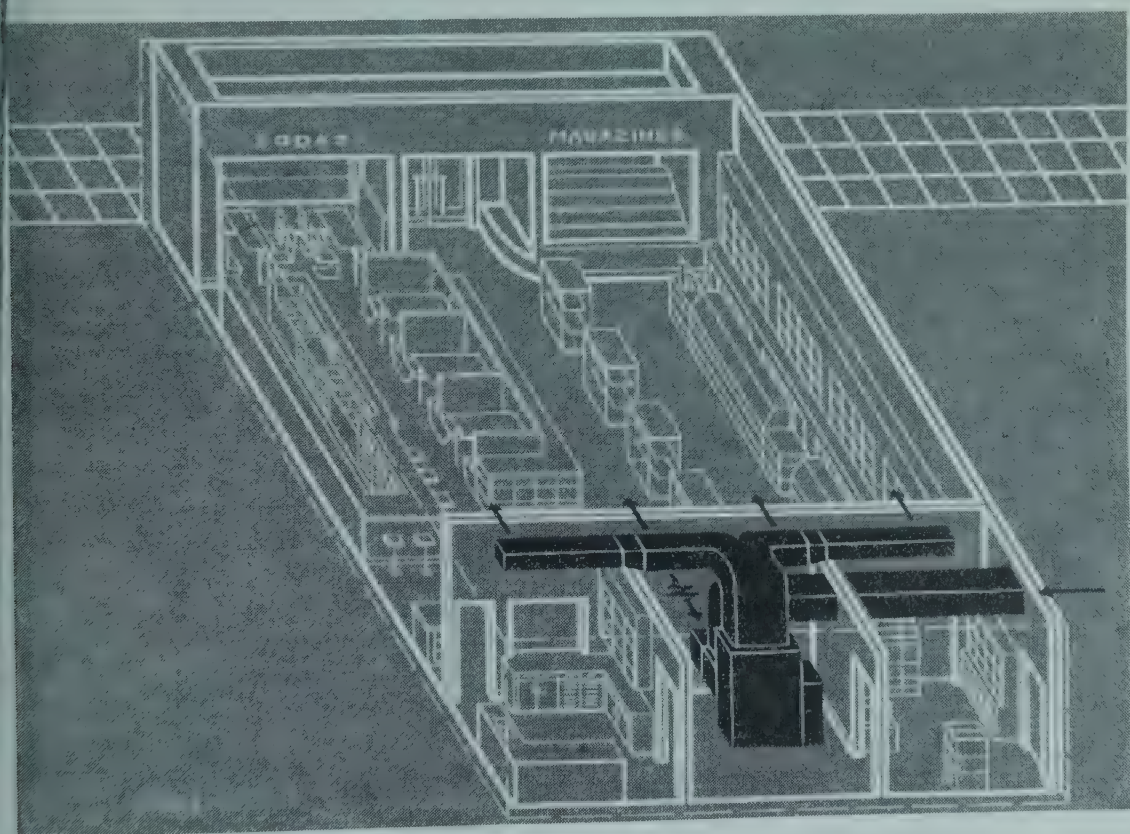


Fig. 3. Central Type Self-Contained Air Conditioning Unit in Drug Store.

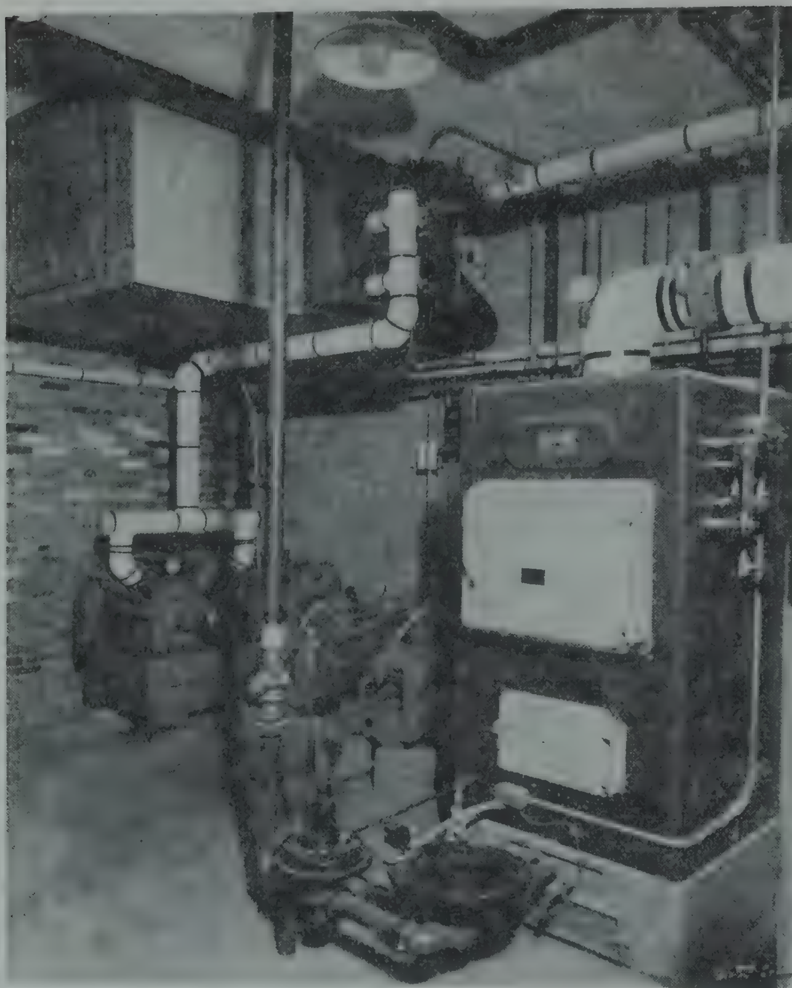


Fig. 4. Typical Built-Up Job for Year Around Operation.

positive introduction of outside air because of relatively large infiltration or small contamination, but this practice is not the best one. Tobacco smoke in particular requires positive ventilation. The expense and appearance of an outside air duct connection to a small unit is sometimes an objection, and in such cases a separate exhaust fan may be installed.

It should be pointed out that a loss in efficiency will result unless all outside air is introduced at the unit so it will be cooled and dehumidified before it is released into the conditioned area. An increase in wet bulb temperature at the entering side of the cooling coil is an easier load to handle than an increase in wet bulb at some point out in the conditioned area.

Automatic Control

The emphasis in the small store field on simplicity and reliability, and contro should be so considered, inasmuch as or dinarily it is not necessary to maintai difficult inside conditions.

Most small unit equipment includ built-in controls adequate for summer sea son use. Field purchased controls are ger erally necessary for the heating function and for cooling and dehumidifying with th larger units as well as built-up equipmen Electric or self-contained controls are ac visable in the small job field. Pneumati controls should be considered if com pressed air is available, and they are mor economical on the large installations.

Control of refrigeration equipment i

usually from a room or return duct thermostat operating the compressor starter. A high-and-low-pressure control is necessary to protect the refrigeration system. Some jobs are best handled by a thermostat operating a liquid refrigerant valve, letting the compressor cycle from suction pressure control.

Heating control requirements are determined by the type of heating employed. The common steam coil on a two-pipe system is best handled by a modulating valve operated from room or return temperatures. One-pipe steam systems, or low-head two-pipe systems must use on-off control. Hot water coils on forced hot water systems can use modulating water valves.

The best practice in heating is to temper the air delivered by the air unit to approximately room temperature or slightly higher, and to use direct radiation or radiant heating at the proper locations to replace heat loss and to provide local comfort. Unless this is done, the same air quantities or distribution can seldom be used satisfactorily for both heating and cooling.

Noise Level

The operation of the system should not cause noticeable noise. Sources of noise are the grilles, outlets, ductwork, fans, motors, drives, compressors, water regulating valves, solenoid valves and other related parts. Noise from the systems is objectionable only when it tends to raise the prevailing noise level. For this reason, a design which is noisy in one instance may be acceptably quiet in another.

Accessories

The smaller self-contained units are usually fully equipped by the manufacturers, and such units require only uncrating, making electrical and plumbing connections, removing of hold down bolts, and starting. Beyond this class of equipment, certain field purchased accessories must always be considered.

Air filters are commonly of the viscous throw-away type, but permanent cleanable filters are popular, ranging from the all metal to the cloth screen types. The electrical precipitating air-cleaner is now practical for general use where its cost can be justified. Since store cleanliness is an important advantage of air conditioning, it is well to be practical and furnish filters which will not require greater maintenance facilities than the owner can be expected to furnish. A poorly maintained filter bank is often worse than none at all. Dirt streaks on walls and ceilings will occur even with the best of filters—a result of smoke and microscopic particles passing the filters and of room air and dirt being aspirated in the air stream. Care should always be taken that all air reaching the room is filtered, with no possibility of leaks or bypasses.

Evaporative condensers and **cooling towers** are to be considered in all cases where the added first cost and maintenance will be offset by water cost savings in a reasonable period of time. The selection is largely dependent on the distance and location of the economizer, as fewer difficulties are involved in piping water than refrigerant. Air-cooled condensers have the advantage of simplicity, but the disadvantage of reduced capacity when greatest cooling is required. Straight air cooling is not generally used above 3 hp.

Water cooling has definite advantages wherever cost is low and adequate quantities are available. There is also the possibility of using the waste water in roof sprays or raw water make-up, some of which uses may make water cost virtually nothing. Where water temperatures permit, it is possible to precool the supply of outside air with a water coil.

If you searched this chapter for something which was not found in it, please let the editors know.

64. EATING AND AMUSEMENT ESTABLISHMENTS

AIR conditioning of restaurants, cafeteria bars, and night clubs presents all of the usual problems encountered in comfort conditioning with the addition of several factors specifically applying to this type of application. Some of these are:

1. Extremely variable loads with high peaks occurring in many cases twice a day.
2. High sensible and latent heat gains due to gas, steam, and electric appliances.
3. High concentration of food, body, and tobacco-smoke odors necessitating adequate ventilation with proper exhaust facilities.
4. Localized high sensible and latent heat gains in night club and dinner club dancing areas.
5. Unbalanced conditions in restaurant area adjacent to kitchens which, although not a part of the conditioned area, require attention.
6. Heavy infiltration of outside air through doors due to high usage factor during "rush hours."

Survey

The first approach to any air conditioning problem is an accurate survey. It is especially important in restaurant applications to obtain all the data relating to time and duration of all **peak loads** caused by people, sunlight, and restaurant equipment. Amusement establishments are often divided into several areas such as a bar, a cocktail room, restaurant and night club; in which case, it is necessary to determine the peak loads in each area since they usually do not occur simultaneously.

During the survey, it is particularly advisable in restaurant and cafeteria applications to advise the owner of any possible improvements that can be made to reduce existing heat gains. Due to the highly concentrated sensible and latent heat loads found in this type of establishment, **reductions** can frequently be made that more than pay for the initial outlay in reduced cost and operating expense of the air conditioning equipment. Items to be considered are as follows:

1. If any **unhooded** or improperly hooded **equipment,** such as coffee urns, steam tables, toasters, grills, etc., are within the conditioned area, they should, if at all possible, be removed to the kitchen, or efficiently designed hoods should be installed.

2. A study should be made of existing **exhaust fans** with the following possibilities in mind:

   a. Their capacity should be reduced if greater than ventilation requires.

   b. Fan connections should be relocated or rearranged to improve hood efficiency or to facilitate smoke removal.

   c. Oversize fans can often be equipped with two-speed motors, or dampers can be provided to permit full-capacity short-period purging. This is of particular value in night clubs and cocktail lounges, where excessive smoking prevails.

   d. Additional supply fans should be provided in kitchen areas to balance any existing exhaust fans and thereby prevent excessive removal of conditioned air from adjacent spaces. In this connection it is sometimes possible to discharge the air from a restaurant exhaust fan directly into the kitchen, thereby giving the kitchen employees the benefit of cooler air and also reducing the capacity

C. L. Nelson, Author Chapter 64. Born 5/12/06, in Oakland, California. Educated at University of Minnesota, ME, 1929. Formerly, Application Engineer, Carrier Corp., Newark, N.J., 1929–30; New York office, 1930–33; air conditioning engineer, Metropolitan Life Insurance Co., New York, N.Y., 1933–34; application engineer, Carrier Corp., Chicago, Ill., 1934–36; chief engineer, Sears and Piou, Inc., St. Louis, Mo., 1936–44; vice president, Air Conditioning Engineers, Inc., Mobile, Ala., 1944–47; chief engineer, The Thermodyne Corp., New York, N.Y., 1947 to date.

Contributor to trade papers; author Chapter 59, 1946 Applications Volume, ASRE Data Books.

Member, Tau Beta Pi.

At present, Chief Engineer, The Thermodyne Corp., New York, N.Y.

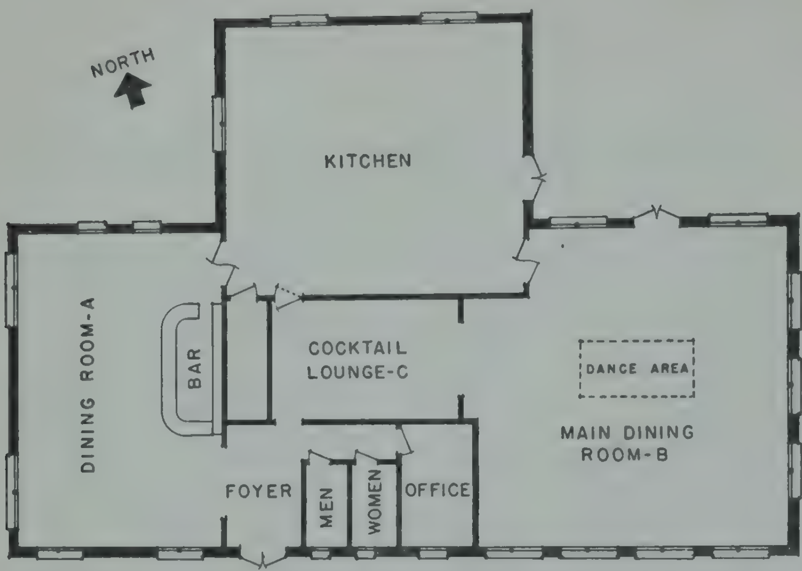


Fig. 1. Floor Plan of Restaurant Building.

of any additional kitchen supply fans required.

3. Other **improvements** which are common to all air conditioning installations should be considered, such as:

a. Insulation of sunlit roof areas

b. Spraying of sunlit roofs with waste condenser water

c. Insulation of floors located over hot kitchens or boiler rooms

d. Installation of awnings or venetian blinds at sunlit glass

e. Installation of vestibules or revolving doors to prevent excessive door infiltration

f. Sealing of openings, and weather-stripping of doors and windows.

Analysis and Division of Zones

After making the survey and before starting the Btu estimate to determine the capacities of equipment required, it is advisable to separate various areas that suggest zoning. Zoning in general may be required due to differences in sunlight exposure or because of variations in people load.

The necessity for zoning is illustrated by **Fig. 1.** Inspection of this restaurant immediately indicates three zones, A, B, and C, on the basis of sun exposure, A having a maximum sunlight gain in the afternoon, B in the morning, and C none at all. On the basis of people, we find that A has peak loads occurring between 12:30 and 2 p.m. and also between 7 and 11 p.m. every day of the week; B peak loads occur between 7 p.m. and 1 a.m. Monday through Saturday and on Sundays between 1 and 3 p.m. also 7 p.m. to midnight; C peaks occur between 3 p.m. and 1 a.m. During the heating season, Zone C, not having an outside exposure, will not require heating, and will require cooling when Zones A and B require heating.

It follows therefore that proper application of zone control for winter conditioning is just as important as for summer. Too often the air conditioning engineer will concentrate his thinking upon the cooling problem only and forget about what might happen in winter. Two winter problems which present themselves frequently in restaurant application are:

1. Windows: It is common practice to place the dining tables next to large windows consequently under-window heating should be provided together with weatherstripped or double sash to provide maximum comfort to the patrons.
2. Doors: The heavy infiltration of outside air through restaurant doors makes it imperative to provide radiation or unit heaters at the doors. The use of a heated vestibule is recommended.

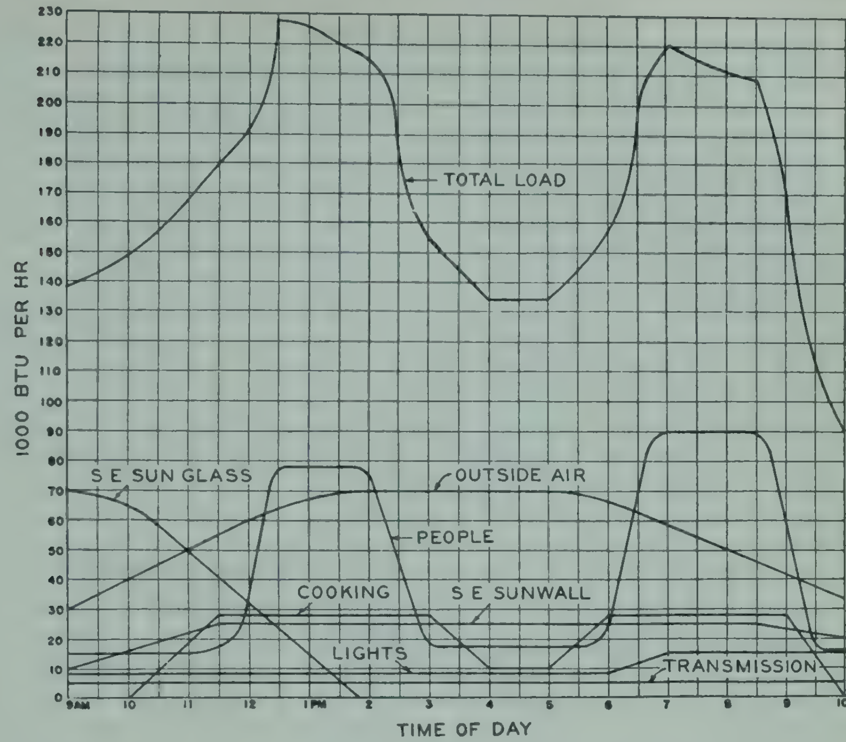


Fig. 2. Hourly Cooling Load Analysis of a Typical Restaurant.

Load Calculations

A detailed heat estimate for each zone is the next step. This will determine the dew point and quantity of air required for the peak load of each area, thereby permitting proper selection of the air handling, heating and low side equipment. To determine the capacity of the refrigerating equipment, a separate combined heat estimate is required. Care should be taken not to pyramid peak loads which do not occur simultaneously or the resultant equipment selection will be larger and more costly than actually required for the application.

In most cases, inspection will indicate at what time of day the peak load occurs, but if this is doubtful, additional Btu estimates should be made. In each estimate, the actual value of the load component which is occurring at the particular time should be used. This is graphically shown in **Fig. 2,** which analyzes the hourly cooling load of a typical restaurant. The use of a simple graph when determining the combined Btu estimate of a multizone application will show at a glance the overall combined peak load to be handled by the refrigeration equipment.

No attempt will be made in this chapter to discuss in detail the various components involved in the preparation of heating and cooling load estimates. (See *Refrigerating Data Book*, basic volume, 5th ed., 1942, and the *A.S.H.V.E. Guide*).

Outside design conditions for various sections of the country are well established by code and complete tables may be found in the *Data Book;* however, these should be checked against the time of day during which the peak combination of components occurs. Very often, the peak loads in restaurants and night clubs occur at night when the outside dry and wet bulb temperatures are substantially lower than published maximums.

Inside design conditions are also well established and basic effective temperatures within the comfort zone should be used. In selecting design conditions the time of patron occupancy should be considered, since those entering for a short stay after exposure to outside extremes are comfortable in a room of higher temperatures than would satisfy those who remain long enough to become acclimated. Published effective temperature data (see *Data Book*, basic vol.) are based on occupancy over and under 40 min. Night clubs and deluxe

restaurants will usually fall in the first classification and should be designed for a lower effective temperature than cafeterias and noon-day restaurants.

Very often, the ideal design condition must be rejected in favor of a poorer but still acceptable one due to cost of equipment required or equipment performance limitations. In changing from the ideal, a condition of equal comfort can be maintained by changing only the combination of dry bulb temperature and relative humidity for the same effective temperature within the comfort zone. Restaurant applications frequently fall in this category, since the high ratio of latent to sensible heat may result in uneconomical equipment selection unless a combination of lower design dry bulb and higher relative humidity (giving equal effective temperature) is selected.

Ventilation standards. The minimum recommended ventilation is 12 cfm per person for restaurants with normal tobacco smoke and odor contamination. This should be substantially increased for cocktail bars, night clubs and similar applications.

Solar heat and transmission factors are common to all types of air conditioning applications and require no special emphasis since they are well known to application engineers. However, it may be well to mention that the effect of heat lag due to the construction of walls and roofs should be carefully analyzed in determining peak loads. The effect of sunlight on a heavy masonry wall may not be felt within the air conditioned space for several hours after exposure, whereas a lightly constructed wall would give full effect almost at once. The wall factor is usually a minor part of the total heat load for a restaurant but the roof gain may be extremely large and therefore the lag effect should be carefully considered in determination of peak loads.

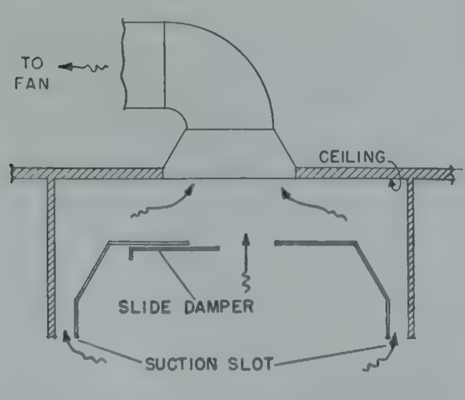


Fig. 3. Section of Exhaust Hood Using Suction Slots.

Internal heat and moisture loads in connection with restaurant air conditioning might well be stressed, since they constitute the greater portion of the load.

1. People. Separate calculations should be made for the patrons and the employees, applying the proper factors for sensible and latent heat for people sitting and at work. It is necessary to proportion the sensible and latent heat in accordance with the inside design temperature selected, since the ratio of latent to sensible heat is reduced as the room temperature is lowered.

2. Motor and light loads require no emphasis, but care should be taken to apply the proper use and load factor.

3. Restaurant appliances. Sensible and latent heat loads from coffee urns, steam tables, etc. are a large factor. Any of this equipment which cannot be moved from the conditioned space should be adequately hooded with positive exhaust. Published values for heat gain from electrical, gas, and steam appliances may be found in the *Refrigerating Data Book*, basic vol., 5th ed., 1942, and the *A.S.H.V.E. Guide.*

The following features should be incorporated in the design of an adequate hood:

a. It should be directly over the appliance and as low as possible to minimize the effect of air cross currents.

b. Positive exhaust should be used since gravity hoods are seldom effective.

c. The higher the face velocity of the hood the better; good practice indicates a minimum of 50 ft per min. Very often the use of standard hoods under these conditions will require more air removal than can be economically delivered by the air conditioning equipment. Since all air exhausted from the conditioned space must be balanced by an equal amount of outside air through the equipment, the

ventilation requirements may be exceeded and result in unsatisfactory equipment selection. Under these conditions it is possible to install especially designed hoods with high velocity peripheral slots and reduce the exhaust air quantity as much as 50 percent. (See **Fig. 3**).

4. Infiltration is a considerable factor in many restaurant applications due to short occupancy resulting in frequent opening of doors. This factor is so variable that good judgment on the part of the application engineer is required. Data as followed in general practice may be found in the *A.S.H.V.E. Guide*. The problem is accentuated because the necessity of large quantities of exhaust air for hoods and smoke exhaust makes it expensive to balance door infiltration with excess outside air through the air conditioning equipment. It is therefore advisable to provide vestibules or revolving doors wherever possible to reduce the infiltration load.

Selection of Equipment

After determining the Btu load for cooling, heating or both, the application engineer is faced with the proper selection of equipment. It is not possible to set down a hard and fast set of rules which immediately indicates whether the equipment should be central station type, self-contained, storage type, etc., because of the varying factors for each application. Regardless of the type selected, good restaurant applications should have the following features:

1. Full **capacity** to handle the peak load with outside air in sufficient quantity to balance all exhaust fans and to meet good ventilation standards.

2. Proper **air distribution** keeping air motion well below 50 ft per min to prevent drafts. A higher air motion is permissible in dance floor areas such as found in night clubs. Air distribution is frequently a difficult problem in restaurants and tap rooms with low beamed ceilings. Care should be taken to avoid air stream impingement on beams and columns, and to secure uniform coverage over the room by supplying air at a sufficiently large number of points. Poor air distribution in existing dining room and restaurant applications is so frequently found that the topic cannot be emphasized too much. One of the worst pitfalls is the propensity to over-blow, with consequent drafts down the walls, or impingement of two streams resulting in turbulence in the breathing zone. Designers should be encouraged to increase outlet area and decrease static pressure in such situations in order to deliberately under-blow. For the critical applications so often found in restaurants with low ceilings and high loadings requiring large air quantities, a suggested order of preference for the type of distribution is as follows:

1. Perforated ceiling
2. Ceiling diffusers
3. Side wall outlets

In some cases #3 is a very poor third and should not be used.

3. Provision should be made for **step control** of refrigeration to give satisfactory and economical operation under reduced loads.

4. Air should be exhausted at the ceiling for removal of smoke and odors where these are a problem. A flushing exhaust is recommended for extreme cases.

Fig. 4. Hotel Cocktail Lounge.

Some factors which influence **equipment selection** are as follows:

1. Building design and space limitations very often favor one type of equipment as against another. For example, a restaurant

having a vestibule with available space above it might indicate a system with the high side equipment in the basement and the low side equipment above the vestibule. Such an arrangement saves valuable space, even though self-contained units located within the conditioned space may prove somewhat lower in first cost. In general, small cafeterias, bars, etc. with loads up to 10 tons can be most economically conditioned with package units, while the larger and more elaborate establishments call for built-up central plants.

2. High **water costs,** scarcity or contaminated supply favor the use of cooling towers or evaporative condensers. It is well to keep in mind that evaporative condensers can be frequently made to serve a dual purpose in conserving water costs as well as removing smoke and odors. In other words, the air required by the evaporative condenser can be drawn from the conditioned space, thus eliminating the necessity for operating additional exhaust fans and also improving the overall efficiency of the plant due to the low wet bulb entering the condenser.

3. The usual practice for the smaller restaurant applications has been to use direct expansion Freon-12 systems. Face and bypass control of the dehumidifier together with at least three steps of refrigeration capacity is one of the most satisfactory methods of controlling the conditions in restaurant applications. This control permits dehumidification to continue throughout the range from light to full load conditions. Large establishments are often handled by circulating chilled water through spray type or finned coil surface dehumidifiers.

4. Some restaurants lend themselves nicely to storage systems involving the use of a smaller refrigeration plant in connection with **ice accumulating coils** submerged in an insulated tank of water. This arrangement is usually only worth considering in connection with restaurants having a high peak of short duration, particularly in a locality where the power demand rate is high.

5. **Solid adsorption** dehydration equipment, while usually more costly, produces superior results where latent heat loads are especially high. This is particularly true of dance floors, where it is difficult to maintain humidities below 60 percent with conventional refrigerating equipment alone. Where cheap and abundant well water of sufficiently low temperature is available for after cooling, absorption or adsorption dehumidifiers may often be economically applied.

6. The **odor and smoke** problem in many restaurant and kindred applications can be mitigated either by ample ventilation or by odor absorption equipment. The economics of the latter may be quite favorable, since it permits selection of a smaller refrigerating plant, and achieves a reduction in both summer and winter operating cost.

If you searched this chapter for something which was not found in it, please let the editors know.

65. MULTI-ROOM BUILDINGS

THIS chapter deals with a study of the requirements and a discussion of representative practice in air conditioning multi-room structures represented by:

1. Office buildings
2. Hotels (guest rooms)
3. Apartment buildings
4. Hospitals (patients' rooms)

Practices have varied considerably in the past, but creditable installations were made in buildings of this type as early as 1926–27. Progress was retarded by economic conditions in the United States during the thirties. During the same period, however, self-contained room units and unit systems were developed and installed for individual rooms and parts of buildings. Though misapplied in many instances, units and unit systems were comparatively low in first cost and, being suited to partial installation, they contributed in a large measure to wider acceptance and increased demand for air conditioning. During these early stages, with systems differing widely, experience was gained which now more clearly defines the types of systems appropriate for multi-room buildings, considering the size, load characteristics and economic factors involved.

Air conditioning of multiroom buildings is obviously different from practices which may be successfully applied to theatres, department stores, or similar buildings having large open areas with a small external heat gain as compared with the internal load. Multi-room buildings have a large percentage of outside rooms and the solar heat gain alone may amount to from 40 to 60 percent of the total sensible heat load (see **Fig. 1**). This external load is constantly shifting throughout the day and necessitates zoning of the building according to exposure. However, the internal load may vary from room to room, and a central zoning system is capable of maintaining, at best, only an average temperature throughout the zone with compromise results in some spaces.

In a theatre the occupant has no choice but to accept an average comfort level. In an office building, however, each tenant rightfully expects acceptable comfort conditions in each room, and in a hotel the temperature level should be subject to selection and adjustment by the occupant of each room.

JOHN M. RACHAL, Author Chapter 65. Born 2/24/06, in Union, Kentucky. Educated at University of Kentucky, BS, 1927. Joined Carrier in their export activities in 1928 and has been associated with installations in Robinson Deep Mine, South Africa, 1932; Bank of China, Shanghai, 1936; Travancore Rayon Mills, India, 1947. Also designed and sold the first theatre air conditioning systems to be installed in South Africa and Siam; the first fish freezing plant to be installed in India; the first air conditioned tea fermentation plant.
At present, General Sales Manager, Carrier International Division, New York, N.Y.

Factors in Design

Special design requirements. To satisfy the requirements of multi-room buildings, aside from the usual functions of year-round air conditioning—namely, ventilation, cleaning, dehumidifying, humidifying, heating, cooling and air circulation—*equipment must provide capacity and flexibility to meet variations in external and internal loads, including adequate simultaneous heating and cooling capacity; means of obtaining individually selected temperatures (within a reasonable range); and maintenance of these temperatures in each room, independent of the others during all seasons.*

Simultaneous capacity for heating or cooling has not been given sufficient consideration in the past. At the end of the so-called cooling season, some systems are stopped or switched over to the winter heating cycle. Obviously, as an examination of weather records will disclose, there are a great many days during the **intermediate seasons** of spring and fall when both heating and cooling are needed. Also,

buildings of this type frequently have large window areas with correspondingly high solar heat gains. Hence on cloudy, humid days in summer when this solar heat is lacking some reheating may be required. Conversely, in winter on bright days, the effect of sun may be sufficient to require cooling of exposed areas. For example, the south exposure may require heating in the morning, cooling during midday and heating again in the afternoon. Such reversals of load cannot be met by the average conventional system. Under certain conditions, the building as a whole may require heating, but a few rooms, due to concentrated internal loads, may require cooling. This condition necessitates capacity for simultaneous heating and cooling being made available at each room independently of the others, with provision for individual control. In the past the failure of systems to meet these conditions has apparently been condoned but, with greater experience and improved practices, no system will be acceptable that does not fulfill these requirements.

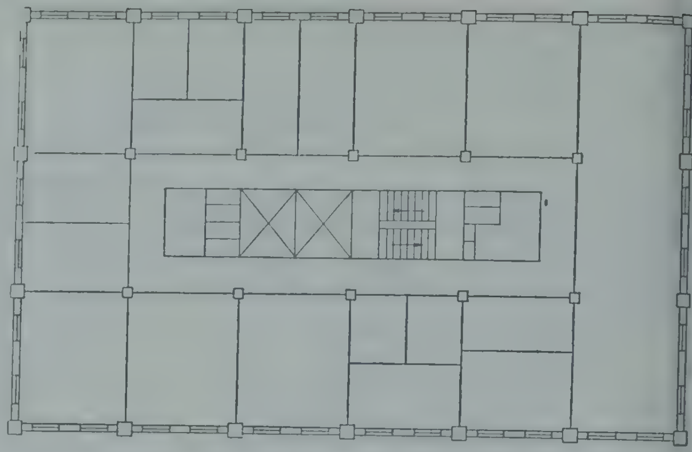


Fig. 1. Typical Office Building Floor Plan.

Zoning requirements. The first approach to a problem of this nature is an examination of the building plans to determine the zoning requirements according to outside exposure. Any multi-story building must as a rule be divided into four zones, usually east, south, west and north. The cooling load varies considerably as the sun progresses around the building and the presence or absence of this solar heat gain is one of the principal reasons for the zoning requirement. A fifth zone is created by any interior spaces with a load largely from people and lights. This interior zone load is relatively constant and is unaffected by outside exposures.

The **peak load** for each outside zone must be determined by a detailed cooling estimate, considering the hours of maximum solar heat gain. These estimates for each zone must be further analyzed to determine the peak load for the building as a whole. Assuming that the sun-exposed walls are of approximately the same area, the building peak will normally occur at 4:00 p.m. on or about August 1 at 40° North Latitude, when the west sun is at a peak and transmission gains may likewise be at a maximum. The tendency, however, to assume that the peak load on all buildings will occur at 4:00 p.m., may frequently be in error. If the time of the peak load is not obvious, the designer should carefully check the load at, say, 2:00 p.m. when the sun may be shining simultaneously on both the south and west windows, or at 10:00 a.m. when the sun is on both east and south windows. Likewise, in the northern hemisphere the angle of incidence of the south sun is decreased during the late fall and early winter, which greatly increases the solar heat gain on a south exposure. While this condition may not increase the load for the building as a whole, it may represent a peak for the south zone. In any case, the proposed zoning should be carefully analyzed for several different hours and for different seasons to insure adequate capacity at any time during the year.

Solar heat gains. Table 1 represents a tabulation of solar heat gains for certain exterior bays of a typical office building. The peak for each exposure is underscored and the peak for this portion of the building is seen to be at 5:00 p.m. The values for solar heat gains have been taken for July 25 at 40° North Latitude (Fig. 2).

Table 1. Load Variations in External Bays for Typical Office Building

Wall	Load	8	9	10	11	12 Noon	1	2	3	4	5
		Time of Day (D.S.T.)									
A	Solar	4000	1850	600	—	—	—	—	—	—	—
E-20°-N	Other	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
	Total	7100	4950	3700	3100	3100	3100	3100	3100	3100	3100
B	Solar	2050	2300	2150	1700	900	225	—	—	—	—
S-20°-E	Other	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
	Total	5150	5400	5250	4800	4000	3325	3100	3100	3100	3100
A-B	Solar	6050	4150	2750	1700	900	255	—	—	—	—
Corner	Other	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400
	Total	10450	8550	7150	6100	5300	4625	4400	4400	4400	4400
C	Solar	—	—	—	—	—	500	1850	3200	3900	4000
S-70°-W	Other	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
	Total	3100	3100	3100	3100	3100	3600	4950	6300	7000	7100
B-C	Solar	2050	2300	2150	1700	900	725	1850	3200	3900	4000
Corner	Other	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400
	Total	6450	6700	6550	6100	5300	5125	6250	7600	8300	8400
D	Solar	—	—	—	—	—	—	900	2350	3600	4300
W-10°-N	Other	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
	Total	3100	3100	3100	3100	3100	3100	4000	5450	6700	7400
E	Solar	—	—	—	—	—	—	—	—	—	300
E-80°-N	Other	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
	Total	3100	3100	3100	3100	3100	3100	3100	3100	3100	3400
D-E	Solar	—	—	—	—	—	—	900	2350	3600	4600
Corner	Other	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400
	Total	4400	4400	4400	4400	4400	4400	5300	6750	8000	9000

The peak load occurs at 5:00 p.m. since the hours listed are daylight saving time corresponding to actual office hours (one hour ahead of sun time). The peak on wall "D" would occur at about 5:00 p.m. sun time since it faces northwest.

Internal loads. Aside from the sun effect, there are other variable loads which must be reckoned with depending upon their relative magnitude. The use of lights will vary from room to room according to the type of work being done and to personal preference. There may likewise be heat loads from business machines in certain areas.

Lighting loads. In accordance with the most recent practice in office buildings, fluorescent lighting will vary from 1.5 to 2.5 watts per sq ft of floor area and incandescent lighting from 2 to 4 watts per sq ft. In some instances where concealed lighting is used, the load may be as high as 6 watts per sq ft, but this is infrequent. In the past, it has been the usual practice to consider that only half the lights in outside sun exposed bays will be in use when the sun is shining and, therefore, only half the heat gain from these lights need be included simultaneously with the maximum solar heat gain. This assumes, however, that the wiring and light switches are so arranged that it is possible to switch off the lights nearest the windows and leave the inner lights burning. However, unless such operation of lights can be assured, the soundness of the assumption is very much in question. One hundred per cent of lighting load must be included in the cooling estimate for inside bays or zones.

In hotels, apartment buildings and hospitals, the average lighting load is about 0.5 watts per sq ft. Such lighting can, as a

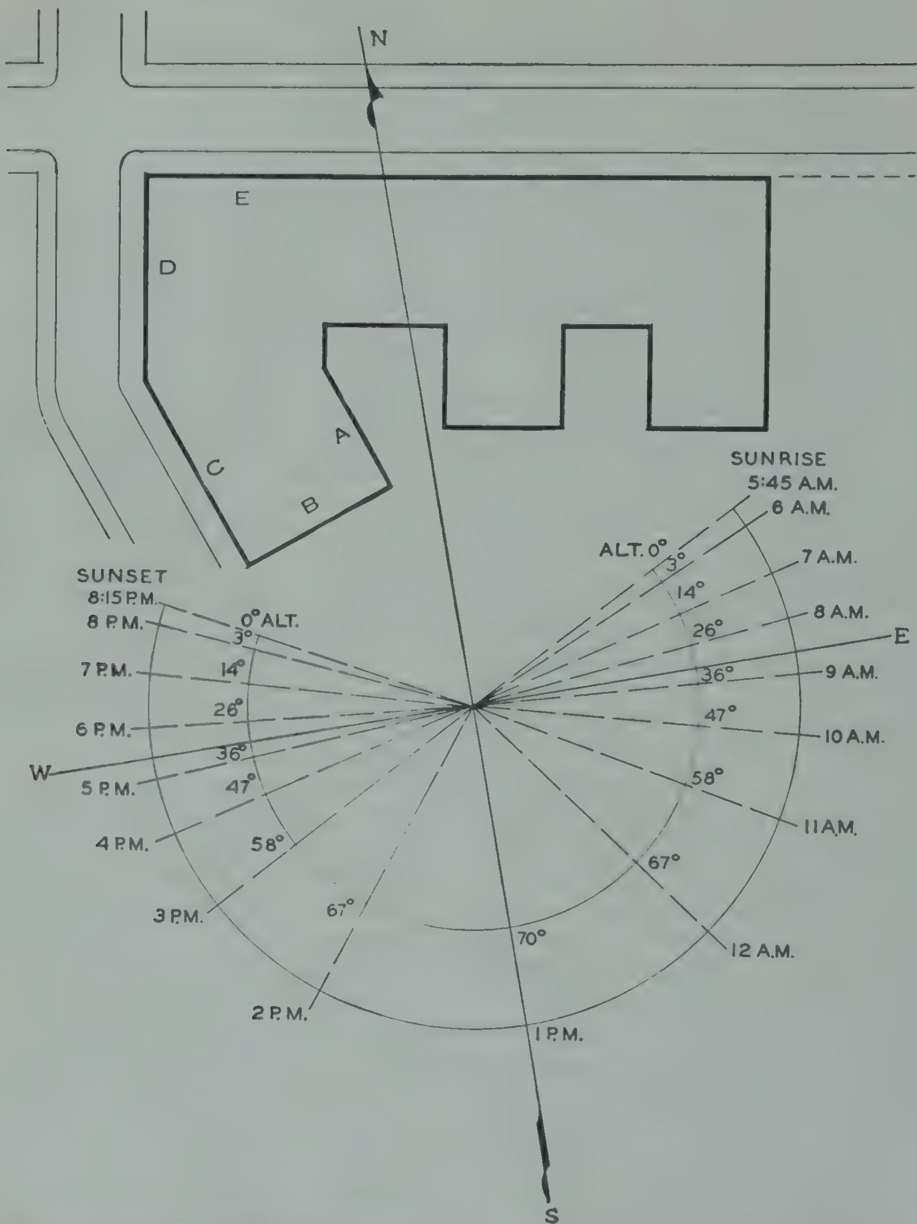


Fig. 2. Block Plan of Office Building; Sun Angles on July 25, 40° North Latitude (Daylight Saving Time).

rule, be ignored in outside rooms or at least considered non-concurrent with maximum sun load.

An important load, frequently overlooked in apartment buildings, is heat gain from piping for hot water services. This has been found to equal on the average as much as 10 percent of the maximum sensible heat load of the entire building.

Occupancy will vary considerably. In accounting or other sections where clerical work is done, the maximum density is approximately one person per 50 sq ft of floor area. Where there are private offices, density may be as little as one person per 200 sq ft. The most serious cases, however, are the occasional waiting rooms, conference rooms, or directors' rooms where the occupancy may be as high as one person per 20 sq ft.

Ventilation requirements. Normally related to the occupancy is the increment of

ıtside air for ventilation. Accepted prac-ce in the past for ventilation in office uildings has been based on 15 cfm per erson on the average, with a further allow-nce up to 30 cfm per person to compen-ıte for smoking in deluxe applications. 'or hotels, apartments and hospital rooms ıe average outside air quantity is likewise 5 cfm with a minimum of 10 cfm per erson. Some designers check the ventila-ion air quantity on an air change basis—ne change per hour being considered a ıinimum.

These standards have been followed in he industry for some years and have found easonable acceptance in buildings where he occupancy is known and unlikely to hange. Frequently in office buildings, how-ever, the tenants and therefore the occu-pancy may change, resulting in a shortage of ventilation in certain areas where the need may be greatest.

Latest practices indicate that the **mini-mum ventilation** in multi-room buildings can best be established on a square foot basis, an accepted figure being .25 cfm per sq ft for office buildings. For example, assume an average bay 20 × 20 ft, or 400 sq ft of floor area, would require 96 cfm ventilation air. Assuming maximum occupancy of six to eight persons as in a general office, the minimum ventilation would be 12 to 15 cfm per person. This should take care of moderate but not exces-sive smoking. If at some future date this same area were converted into an executive office occupied by, say, two persons, the ventilation air would then equal 48 cfm per person, which would be entirely ade-quate and would compensate for some ex-cessive smoking. It will be seen, therefore, that ventilation air quantities established on a square foot basis will insure adequate ventilation for any reasonable change in occupancy. On this basis, the standards for multi-room buildings are as given in **Table 2**.

These figures represent minimum venti-lation requirements. Systems supplying a fixed quantity of outside air at all times are preferred, or the control should be such that the quantity of ventilation air is not reduced below these minimum figures un-der any conditions.

Table 2. Ventilation Standards for Multi-Room Buildings

Type of building	Outside air per sq ft floor area, cfm
Office buildings	.25
Apartment buildings	.33
Hotels (guest rooms)	.25*
Hospitals (patients' rooms)	.33

* Minimum per room 50 cfm.

The principal function of the ventilation air is to establish **odor control** through di-lution (body odors, tobacco smoke, etc.), and the vitiated air is relieved from the room and carried off by an exhaust system. The standards outlined will insure a fresh, clear atmosphere, but closely coupled with ventilation is adequate humidity control. A source of odors and mustiness in build-ings arises from the effect of relative hu-midities above about 55 percent on the walls, floors, furniture and furnishings of the average building. Relative humidities of from 40 to 50 percent or lower are there-fore preferred.

Table 3 lists check figures for cooling estimates for representative multi-room buildings.

In buildings where the tenantry is known, provision can be made in the initial design to compensate for any abnormal load conditions. In the average office building, however, tenants change frequently and the entire arrangement of the offices may likewise change. There is a practical limit to the design factors without pyramiding loads, but such variables must be given con-sideration. The system which provides the greatest flexibility and adequate capacity to meet tenant and load changes will give the greatest satisfaction to the owner and user.

Relation of zoning to building shape. Another factor affecting the zoning is the building size and shape. A single story multi-room building is a type in itself. It is perhaps the simplest in that all zones have a common roof load and the possibili-ties of variations within the zone are at a minimum. Nevertheless, the need for zon-ing exists and can be met with horizontal treatment. Frequently, however, due to

the size of such a building, complete zoning may not be practical or may be curtailed for economic reasons, and the system confined to a single plant with reheating or volume control, or a combination of both. (For a discussion of the limitations of volume control, see *Zoning Methods.*)

In multi-story buildings, **vertical zoning** is commonly used. Depending upon the height of the building, one or more sets of conditioning equipment are supplied with one or more fans per zone according to size, available space for ducts, etc. Vertical zoning is well adapted to tall narrow buildings.

There are some disadvantages, especially due to heat gains to the first office floor, if there is no conditioned space below, and heat gains through the roof on the top floor. If these areas are sufficiently large, they should be considered as a separate zone, otherwise separate control for both heating and cooling is required with some compromise in results. Vertical zoning is likewise subject to the unfavorable effect of moving shadows created by adjacent buildings. Where building size and economics permit, horizontal treatment of each floor with a separate recirculation fan for each zone is preferable.

The zoning requirements which have been discussed previously apply largely to the cooling loads resulting from solar heat gains on the outside walls. Such zoning is essential to the economic and successful operation of the system and permits selection of the refrigerating plant for the simultaneous peak load on the building with corresponding saving in cost. The system will provide satisfactory results during both the cooling and heating seasons, providing the outside load is uniform throughout the zone and internal load likewise uniform and constant. However, in multi-room buildings the results will not be considered satisfactory when the internal load varies, particularly during intermediate seasons of spring and fall. If the variation in internal load is sufficiently great so as to cause a reversal of load within any part of the zone, then the systems of central zoning fail completely. Under these conditions the systems which provide simultaneous capacity for heating and cooling, with means of individual control at each room, insure the greatest satisfaction. These points must be weighed carefully in determining the type of zoning to be employed.

Table 3. Check Figures for Cooling Estimates*

Classification	**Grand total heat			**Room sensible heat			Sq ft per person			Watts per sq ft		
	Low	Avg	High	Low	Avg	High	Low	Avg	High	Low	Avg	High
Apartments and hotel guest rooms	13	20	30	9	12	17	100	175	325	.2	.6	.9
Office buildings	23	36	52	19	26	37	81	110	130	.83	1.66	2.60

* These figures are taken in part from Chap. 19, p. 445, "Modern Air Conditioning, Heating and Ventilating," by Carrier, Cherne and Grant (Pitman).
** Btu per hr per sq ft.

Zoning Methods

A study of the preceding indicates that two zoning principles should be considered; namely, central zoning and individual room zoning.

Central zoning is applied to sections of the building having similar outside exposures, also to the interior zones, if any. **Individual room zoning** involves the same principles but applied to each room. A combination of both will provide the greatest flexibility and economy, and fulfill all the requirements of multi-room buildings. Zoning methods most commonly used are:

1. Central zoning
   a. Separate apparatus

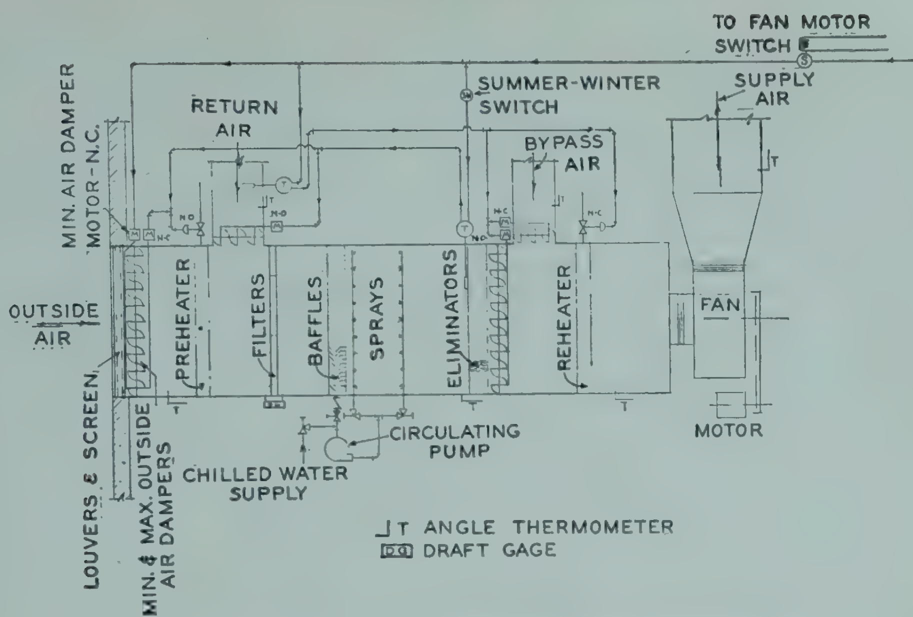


Fig. 3. Central System with Bypass and Reheat for Single Zone.

b. Reheating or recooling
c. Recirculating fans
d. Dual duct system
e. Volume dampers.

A brief description of each zoning method follows:

1. (a) Separate apparatus. This consists of a complete conditioner for each zone (see **Fig. 3**). When furnished with heating coils this system will provide the necessary heating or cooling for the zone independent of other zones. The air handling equipment is selected for the zone peak and the cost for the building as a whole may therefore be high. It is preferable to connect the air handling equipment to a central refrigerating plant so that the latter may be selected for the building peak load with corresponding saving in first cost. Operating cost and results depend upon the type of control and capacity regulation used.

The same principles are applied to individual room zoning under paragraphs 2(a) and 2(b). The differences are in size only.

(b) Reheating or recooling. This is perhaps the simplest type of zoning system but costs more to operate. The arrangement may consist of a single air conditioner and refrigerating plant with a separate air distribution system with reheaters for each zone. All of the air must be cooled to satisfy the requirement of the zone under peak load, and reheat is used for all the remaining zones. Such a system provides excellent control but requires use of both power and steam. Both the air handling equipment and the refrigerating equipment must be selected for the summation of the zone peak loads and thus the first cost of the system is high.

The principle of reheating may be applied to individual room zoning with a separate heater and control for each room.

(c) Recirculating fans. This system consists of a central conditioner and refrigerating plant, both sized for the maximum simultaneous load on the building. The central air conditioner supplies air to separate recirculating fans for each zone (see **Fig. 4**). These fans and their air distribution system are selected for the zone peak load. The system is very flexible and, when each recirculation fan is provided with a reheater, can provide heating or cooling to any zone independently of the others. The cost of the system is moderate and through the use of bypass control there are corresponding operating economies. Proper design avoids impairment of ventilation at reduced loads.

(d) Dual duct system. This system consists of two supply ducts running side by side, one carrying hot air and the other

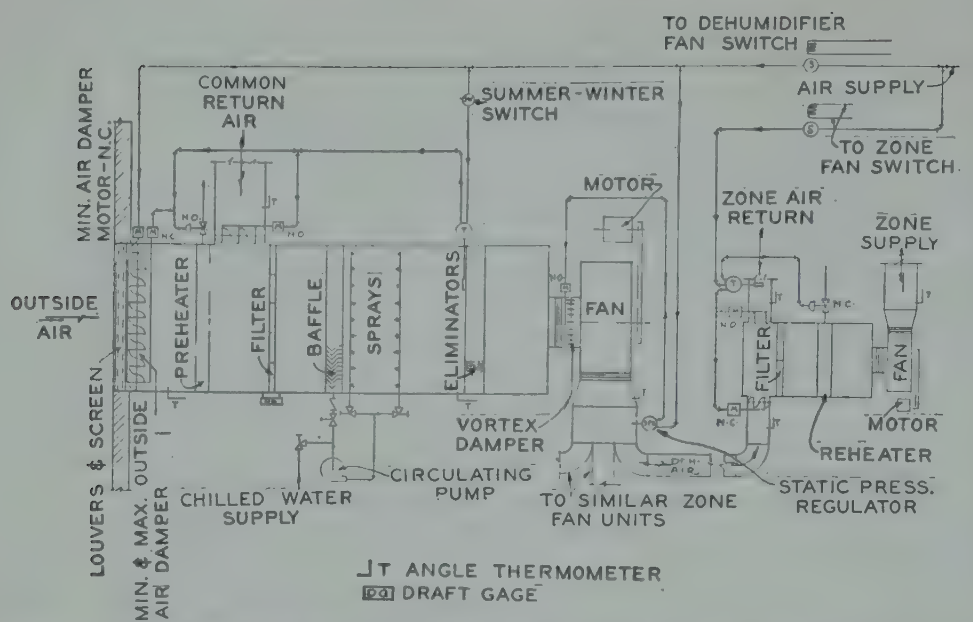


Fig. 4. Central System with Supply Fan and Remote Recirculation Fan with Bypass and Reheat for Each Zone.

cold air with mixing dampers to control the air supply to each zone. Air is usually supplied to the dual duct system from separate central cooling and heating plants, but, with this arrangement, if untreated outside air is bypassed through the heating system, the control of humidity is lost.

Normally a single fan supplies air through a dual duct system to each zone. One of the ducts for each zone is equipped with a reheating coil and individual room control is obtained by means of mixing dampers at the outlets. This system provides substantially constant air volume and ventilation.

(e) Volume dampers. Volume control, although the least expensive and most frequently used method of zoning, produces the poorest results. In its simplest form, volume control consists of a damper in the supply duct to a particular zone which throttles the air quantity and thus restricts the heating or cooling capacity as the load is reduced. This type of control has some serious disadvantages. When the air supply is throttled, ventilation is impaired and air circulation is restricted, causing spotty distribution and drafts. Any throttling of the air supply reduces the outlet pressure which shortens the length of blow. Coupled with this, any reduction in air quantity and, therefore, load on the refrigerating plant may result in a drop in air delivery temperature and this, together with the reduced outlet pressure, causes spilling of chilled air which is highly objectionable.

With conventional low pressure systems the operation of the volume dampers for one zone will unbalance the air supply to other zones. Static pressure regulation is essential but only partially alleviates the condition.

Volume dampers may likewise be used for individual room control, but any change in damper position for one room will affect adjacent rooms. Since low pressure systems of air distribution are extremely sensitive to changes in pressure, satisfactory balancing of a system of this type is very difficult.

To avoid shutting off ventilation and to maintain reasonable air circulation, the action of volume control should be limited to about 50 percent reduction in air volume. Any further control requirement at reduced loads is met by the use of a reheater (see **Fig. 5**).

Classification of Systems

Since there are so many variations of

ntral and unit systems, and combinaons partaking of the functional and physal features of both, for purposes of this hapter systems are arbitrarily divided as llows:

Central Systems where the most imortant functions are performed **outside** ie conditioned space, either by central aparatus or scattered remotely-located units.

Room Unit Systems where the most imortant functions are performed inside the oom to be conditioned (even though other unctions may be performed centrally).

This classification, while somewhat arbirary, is useful for purposes of analysis. The following systems are discussed:

- **I. Central Systems**
  - A. Central Station Systems
  - B. Decentralized Unit Systems
  - C. Induction Reheat Systems
- **II. Room Unit Systems**
  - A. Ventilating Unit Systems
    - 1. Self contained units
    - 2. Ventilating fan-coil units
  - B. Primary-air Unit Systems
    - 1. Fan-coil units
    - 2. Induction units

. Central Systems.

A. Central Station Systems. In buildings, central systems have been used consisting of one or more sets of air conditioning equipment located in the basement or in suitable machine rooms on the roof or both. These central plants supply conditioned air to recirculation fans distributed according to the zoning requirements. In the case of a small building with a limited number of zones, the recirculation fans may be located at the air conditioners. This arrangement requires larger supply and return ducts, since all of the air must be circulated to and from the zone. In large buildings having large zones the size of the ducts must of necessity be reduced to a minimum and, in this case, conditioned air is supplied to recirculating fans located within the zones in different parts of the building. This reduces both supply and return ducts since the air is recirculated locally at the zone fan. The former arrangement, with all of the apparatus located at one or two central points, is of course the simplest arrangement from the standpoint of maintenance and operation. However, recirculation fans located throughout the building do not represent a serious maintenance problem.

Central systems may also be used with other methods of zoning, the simplest and

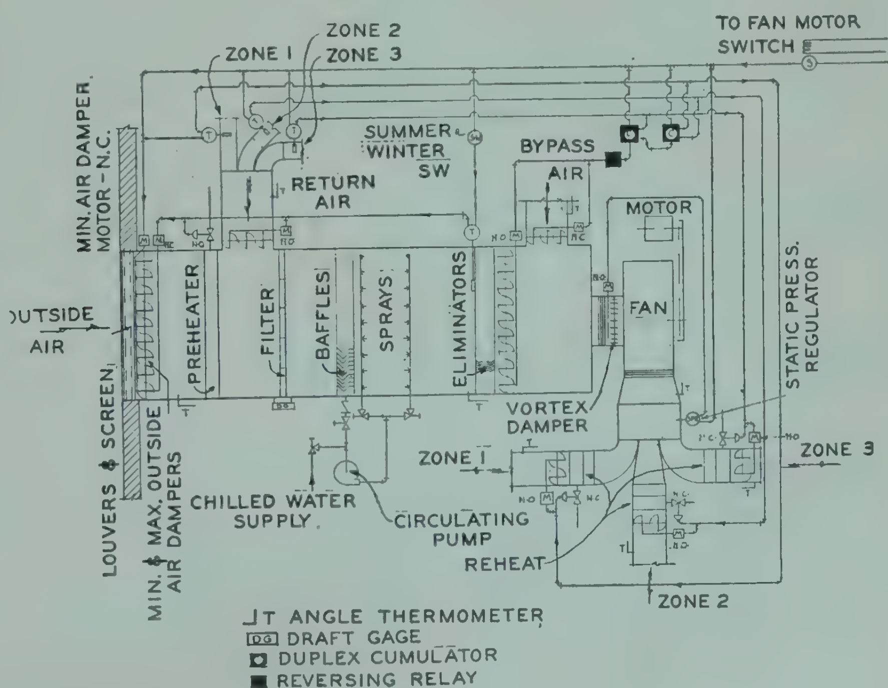


Fig. 5. Central System with Economy Bypass and with Volume Control and Reheat for Each Zone.

Table 4. Comparison of Zoning Methods for Multi-Room Buildings

No.	Type of zoning	Air volumes Supply	Air volumes Ventilation	Equipment size Air conditioner	Equipment size Refrigeration	Simultaneous heating and cooling Each zone	Simultaneous heating and cooling Each room	Control Each zone	Control Each room	Comparative first cost	Comparative operating cost	Comparative results
1.	Multiple Zone Systems											
a.	Separate apparatus											
	On-off control	Constant	Constant	Maximum load each zone	Maximum bldg. load	Yes	No	Yes	None	Medium	Low	Poor
	Bypass control	Constant	Variable	Maximum load each zone	Maximum bldg. load	Yes	No	Yes	None	High	Fairly low	Fair
	Reheat	Constant	Constant	Maximum load each zone	Summation of zone maximums	Yes	No	Yes	None	High	Medium	Fair
b.	Reheating or recooling	Constant	Constant	Maximum load each zone	Summation of zone maximums	Yes	No	Yes	None	Medium	High	Good
c.	Recirculating fans	Constant	Variable	Maximum bldg. load	Maximum bldg. load	No	No	Yes	None	Medium	Medium	Fair
	With reheaters	Constant	Variable	Maximum bldg. load	Maximum bldg. load	Yes	No	Yes	None	Medium	Medium	Good
d.	Dual duct system	Constant	Constant	Maximum bldg. load	Maximum bldg. load	Yes	Yes	Yes	Yes	High	Medium	Fair
	With reheaters	Constant	Constant	Maximum bldg. load	Summation of zone maximum	Yes	Yes	Yes	Yes	High	High	Good
e.	Volume dampers	Variable	Variable	Maximum bldg. load	Summation of zone maximum	No	No	Yes	Yes	Low	Medium	Poor
	With reheaters	Variable	Variable	Maximum bldg. load		Yes	No	Yes	Yes	Low	Medium	Fair
2.	Room unit systems											
a.	Self-contained units											
	On-off control	Constant	Constant	Maximum load each zone	Maximum load each zone	No	No	Yes	Yes	Low	Low	Poor
	Reheat control	Constant	Constant	Maximum load each zone	Maximum load each zone	Yes	Yes	Yes	Yes	Low	High	Good
b.	Ventilating type system	Constant	Variable	Maximum load each zone	Maximum bldg. load	No	No	Yes	Yes	Medium	Medium	Fair
c.	Primary air-fan coil unit	Constant	Constant	Maximum load each zone	Maximum bldg. load	Yes	Yes	Yes	Yes	High	High	Good
d.	Primary air-induction unit	Constant	Constant	Summation of zone maximum	**Maximum bldg. load	Yes	Yes	Yes	Yes	High	High	Good
e.	Reheating induction units											
	With reheat control	Constant	Constant	Summation of zone maximum	*Summation of zone maximum	Yes	Yes	Yes	Yes	High	High	Good
	With volume control	Variable	Variable	Maximum bldg. load	Maximum bldg. load	Yes	Yes	Yes	Yes	High	Medium	Fair

least expensive arrangement being a single central conditioner and a single supply and return duct system with volume control. This of course results in variable air circulation and restricted ventilation. These objections can be met with reheat control which is likewise low in first cost but expensive to operate. A combination of volume control and reheat gives best results and greatest economy from both systems. The dual duct system for zoning may likewise be used with central systems. This arrangement has the advantage of practically constant air volume, constant ventilation, and capacity for simultaneous heating and cooling within the zone; it is thus best suited to individual room control. The first cost of such systems is comparatively high, the duct system and control are complex but the operating cost is medium and the results good.

Central systems are usually designed for year-round operation. They have been used for both cooling and heating, but such practice must be followed with caution to avoid complaint of downdrafts at windows. In colder climates the system is not suitable for heating, but should operate in conjunction with direct radiation or convectors installed under the windows to insure comfort. The system provides ventilation and humidity control the year round. It is necessary to provide reheaters for each zone for tempering the air supply and maintaining proper zone control. The central conditioner may be of the spray or combination spray and surface type. When provided with an adequate intake for 100 percent outside air, the system is superior to any for operation during intermediate seasons by evaporative cooling. Where interior zones occur, this provides a source of cooling during winter. Filters should be furnished at the outside air intake and at each recirculation fan when used.

B. Decentralized Unit Systems. Practically all manufacturers in the United States offer a line of standardized factory assembled fan coil units which have application in multi-room buildings. These units vary in size from approximately 1,000 to 15,000 cfm capacity and consist normally of a fan or fans, cooling coils suitable for chilled water or direct expansion, drip pan, filters and accessories. This equipment occupies comparatively small floor space and in many cases may be suspended from the ceiling of store rooms or other unimportant space, thus saving valuable rentable area.

At least four of the zoning methods previously outlined may be employed. In large buildings a separate unit may be supplied for each zone on each floor. This is, of course, the most satisfactory arrangement. For smaller buildings or where capacity and space permit, a unit may serve several floors of the same zone vertically, a method consistent with good zoning practice as previously outlined.

Both the **fan** and **coil capacity** of these units must be selected for the maximum or peak load within the zone. All of the units are normally connected to a central refrigerating plant which may be selected for the simultaneous peak load for the building. For smaller buildings and where municipal codes permit, direct expansion may be employed.

Usual practice, however, consists of circulating chilled water to the coils. With suitable coils comparatively small water quantities with high temperature rise may be employed with favorable overall economy.

The units may be equipped with heating coils for winter operation. In northern climates these will be for tempering only—for heating the ventilation air to room temperature—since the heat losses from the building as well as the control of the heating will be handled by direct radiation. The tempering coil should be of the non-freeze type. Extreme care must be taken with chilled water coils to drain them completely after the summer season to avoid any danger of freezing in winter.

Since the system must provide ventilation both summer and winter, an outside air intake should be provided for each unit. In tall buildings these multiple individual intakes frequently give trouble from wind pressure and stack effect. Separate filters are required for each conditioner and, when there is a large number of units scattered throughout a building, the cost of maintenance and attendance is comparatively high. Preferred practice employs an outside air fan, shaft and filters to serve a number of units.

A variation of this system which is finding increased use, consists of a number of properly zoned units located throughout the building, supplied from a central plant with primary air conditioned to provide ventilation and humidity control both summer and winter (see **Fig. 6**). Each unit is provided with a chilled water coil for sensible heat cooling only. Such a system eliminates multiple air intakes and provides central filtering. With this system, temperature control is simplified as it is possible to throttle the water supply or to raise the water temperature with corresponding saving in power. This is possible when removing sensible heat only, since the dew point is controlled at the central or primary air conditioner.

There is a further advantage from this type of system in that the largest part of the total refrigeration load can be carried at a comparatively high suction temperaature with chilled water as high as 55 to 60 F circulated to the various units and to a precooling coil in the primary air conditioner. The remaining part of the load can be handled by a separate refrigerating compressor (either for water cooling or direct expansion), operating at a lower suction temperature to cool and dehumidify the primary air to the final dew point temperature desired. Since with this two-level refrigeration a large percentage of the load is carried at the higher suction level, power saving of as much as 25 percent may be attained; likewise smaller compressors may be used.

When such units are used for an **interior zone** it is essential that they be provided with the necessary outside air as the cooling medium in winter. Alternatively, the cooling tower can be designed for winter operation and tower water circulated through the coils to take care of the winter cooling requirements. This may also apply to exterior zones with high internal loads.

Insofar as **individual room control** is concerned, which is one of the essential requirements of multi-room buildings, the unit systems previously described are subject to the several shortcomings of the different zoning systems described. If volume control is used, both air circulation and ventilation are reduced. Both reheat and double duct systems overcome these objections.

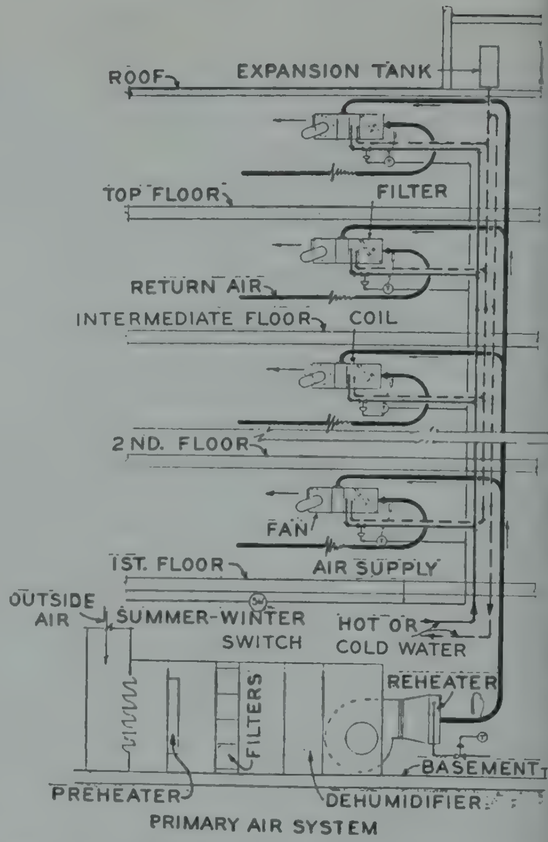


Fig. 6. Central Primary Air System with Remote Fan-Coil Unit for Each Zone.

Apartment building systems. A further application for units is in apartment buildings. A separate unit is installed in each apartment suspended above the ceiling of the foyer or bathroom, with a short duct system to supply air to each of the rooms. Air is returned to the unit through a single grille, usually in the hallway. Since the majority of individual apartments have only a single outside exposure, or at the most two exposures, reasonable zoning is obtained by this method. Control can be effected by means of a thermostat controlling a bypass damper which will maintain an average temperature in the rooms. Further regulation can be obtained by manual operation of volume dampers to each room. This is of some advantage in an individual apartment in that the air can be throttled to the bedrooms and diverted to the living room or dining room when a number of people are present. Each unit

should be provided with an outside air intake for ventilation, complete with filters and accessories.

In colder climates, heating should be handled by direct radiation where single glass is used. If the unit is operated in winter for ventilation, a tempering coil must be provided. Humidity control is sometimes included by means of a pan humidifier and automatic controls.

It is the usual practice to relieve the excess ventilation air through the bathroom and/or kitchen. A mechanical exhaust system for this purpose is preferred.

The system with individual units in each apartment has many advantages. Each apartment becomes a separate zone with the temperature, air regulation, etc. under the control of each tenant without affecting his neighbor. Danger of noise or crosstalk between apartments through a duct system is eliminated. Any odors from cooking are confined to the apartment and carried off through the exhaust system.

The air conditioning unit should be sized for the peak load in each apartment, but the peak loads for each room need not be pyramided since the air can be diverted from one room to another as desired. The central refrigerating plant should be sized for the peak load on the building. If chilled water of the same temperature is supplied to all units, there may be some tendency to rob refrigeration by units not at peak load. However, if current procedure and factors are used in calculating the load, the storage effect of 24-hr operation will carry the plant through practically any peak loads.

A further improvement on the system outlined can be realized through the use of a central primary air system to supply conditioned ventilation air through risers to each of the units. The units are supplied with chilled water for sensible cooling only. This minimizes condensation on coils, reduces odors, and simplifies control by permitting the throttling of chilled water. Individual air intakes are not required, and the primary air system provides ventilation and humidity control in winter.

C. Induction Reheat Systems.—This system makes use of a room unit commonly known as a low pressure induction unit or blender unit. It is, in effect, a form of outlet incorporating a reheat coil, and is designed to be placed on the outside wall of a building in an under-window location. The conditioned air to the unit is supplied through a duct system from a central apparatus which may handle several rooms or an entire building. In general the treatment of the central apparatus is similar to that described under the heading "Central Systems" or "Multiple Zone Systems."

The air is discharged within the unit through a nozzle structure at a pressure somewhat higher than would be conventional practice (in the range of ⅛″ to ½″ wg). The discharge of air at high velocity causes the unit to operate as an ejector pulling air from the room into the unit where it mixes with the air supplied from the central apparatus and discharges into the room.

A heating coil is employed which may be supplied with either hot water or steam. In one design the heating coil is in the path of the mixed supply and recirculated air, whereas with another construction the heating coil is disposed in the path of the return air from the room. These units have the advantage of providing gravity heating for winter operation at times when the central air supply system is not in operation. (See Fig. 7.)

The preferred method of operating these systems is to supply the dehumidified air from a central apparatus controlled according to exposure zones with the final point of control being in the room and taking the form of throttling the heat supply to the reheat coil. This system then operates in a similar manner both summer and winter with cool air being supplied in either case and reheating taking place in the room.

However, such units are also available with throttling dampers which will act to reduce the quantity of supply air discharged from the unit. In some installations the only means of control for summer operation is to throttle the supply damper under command of a room thermostat. This possesses many of the disadvantages of volume damper control cited previously. However, since the unit is designed to operate at a relatively high static pressure less difficulty is encountered due to system unbalance than would be the case with a con-

ventional duct system, and the under-window location gives good air distribution even under reduced volume.

Another form of control makes use of a limited throttling of the supply air followed by the admission of heating fluid to the coil, this operation taking place in sequence under the command of the room thermostat. Thus, only a relatively small percentage reduction in supply air quantity is obtained before the reheating action takes place.

Systems of this type are widely used and can give extremely satisfactory individual room control. The location of the air discharge under the window means that a separate system of direct radiation is not required for winter operation in colder climates since the discharge of the air beneath the window effectively blankets the window, thus preventing the occurrence of cold down drafts or bad problems of stratification.

A disadvantage of this system as applied to very tall structures is found in the amount of space required for apparatus and the relatively large ducts required to deliver the air to the units. Duct sizes are large because all of the room cooling load must be taken care of by the air which is supplied from remotely located air conditioning units. However, as compared to conventional duct systems some saving in space is realized because of the vertical distribution system usually employed and because somewhat higher duct velocities may be used as a result of the inherently greater stability of the higher pressure maintained at the outlet. Somewhat cooler air and therefore lower air quantities may be employed in such systems because of the mixing which takes place within the induction unit and because of the vertical type of air distribution which precludes the possibility of cold down drafts.

II. Room Unit Systems

The zone systems just described, all employ air cooled at a remote apparatus for absorbing the cooling load in the individual rooms. Such systems therefore involve somewhat extended duct systems which in large multi-room buildings take up considerable floor space or may require additional floor to floor height where ducts are furred down from the ceiling.

There are several systems for multi-room air conditioning which absorb the room cooling load (either all or in part) by means of extended heat transfer surface located in each room and supplied with either chilled water circulated from a central water cooling plant or in some cases refrigerant for direct expansion in the cooling coils.

The use of the central system or multiple zone system may also be penalized if proper fire-safety precautions are observed. Fire underwriters and many building codes will not permit the use of corridors for the return of air to the remote apparatus particularly in hotels, apartments, and hospitals. In a large building this requires an extensive return duct system which uses valuable head room and adds to the expense. Systems which employ local cooling in the room, eliminate the return of air to the apparatus and are not penalized by these requirements.

Two general types of systems are applied:

a. Ventilating-unit systems which provide latent heat removal and furnish ventilation air locally in each room.
b. Primary air systems which furnish ventilation air and control of room humidity by means of a relatively small quantity of air treated in central dehumidifying apparatus and distributed through ducts or conduits to the individual rooms. The units provide only sensible cooling or heating.

A. Ventilating Unit Systems. Two types of systems are commonly used:

a. Self contained room air conditioners.
b. Ventilating fan-coil units supplied with chilled water from a central water cooling plant.

In general, such systems pose certain problems in their application:

1. The ventilation air quantity is difficult to control as undesirable increases or decreases may occur due to wind pressure or stack effect in tall buildings.
2. The local admission of outside air re-

quires efficient filtering at each unit and leads to a requirement for considerable maintenance on the many individual filters.

3. If the coil must be controlled from room temperature to allow for reduction of room sensible heat load, control over room humidity may be lost as dehumidifying capacity is cut off and moisture laden outside air may be introduced without treatment.

On the other hand such systems lend themselves to partial or progressive installation better than most other systems.

Following is a more detailed discussion of the two general types of system in this category:

1. Self Contained Room Air Conditioners. The use of self contained room air conditioners for providing summer air conditioning to multi-room structures is becoming increasingly important. This equipment has achieved moderately large annual production volume, with the result that initial cost compares favorably with, and is frequently less than, multiple zone or central systems.

Most of the units currently produced, whether of the window sill or console type, use outside air as the heat rejection medium, and are therefore independent of water supply. Rejection of condensate from the cooling coil into the effluent condenser air stream avoids the need for drain piping. Ventilation is drawn from the condenser air supply through the same intake which is usually disposed between the lower sash and sill of a double hung window. Installation of such units is therefore a comparatively simple matter, requiring only electrical connections and fitting at the window.

Most of these units do not provide winter heating, although some models may be furnished with electric strip heaters for limited tempering duty, advantageous primarily in mild climates. Normally the existing heating system in the building, usually direct radiation, is employed during the winter, with the air conditioner shut down altogether, or employed only for ventilation. In some cases the unit is removed entirely during the winter season, but this practice is becoming more rare.

Power supply is frequently a problem, with the trend on the part of electric utilities to insist on 220 volt supply for units larger than $\frac{1}{2}$ hp. Frequently new power wiring is required when large quantities of units are added to existing buildings.

In common with other units which draw outside air from the side of the building, the ventilation rate is uncertain and variable since it is dependent upon stack effect and wind pressure. The maintenance of these units will probably be considerably higher than for centralized equipment, although the recent trends toward better accessibility of moving parts and use of hermetic compressors has improved the situation measurably.

Control is personalized and at the discretion of the occupant, and this is advantageous. Manual control is the accepted practice, but thermostatic control is sound in principle and its greater adoption can be anticipated.

Noise level is generally higher than most other systems herein discussed, but is satisfactory for many applications and further technological improvements toward noise elimination can be expected.

2. Ventilating Fan-Coil Unit Systems. Another type of unit is the floor-mounted individual room unit, ranging in size from, say $\frac{1}{2}$ to $1\frac{1}{2}$ tons capacity, and from approximately 200 to 500 cfm. These units consist of a coil for chilled or warm water, supplied from a central source and a quiet operating fan assembled in an ornanental casing. The unit is provided with an outside air intake with filter and damper regulator.

The units are normally installed under the window, one or more per room according to load.

Some of the problems attendant to the use of fan-coil units of this type can be alleviated by the use of a separate high pressure fan for handling the outside air admission. This will minimize wind pressure and stack effect. A unit is available which in addition to the outside air fan incorporates a separate dehumidifier coil with the water circulated in a series relationship with the sensible cooling coil for the purpose of separately dehumidifying the outside air. The use of this coil improves the

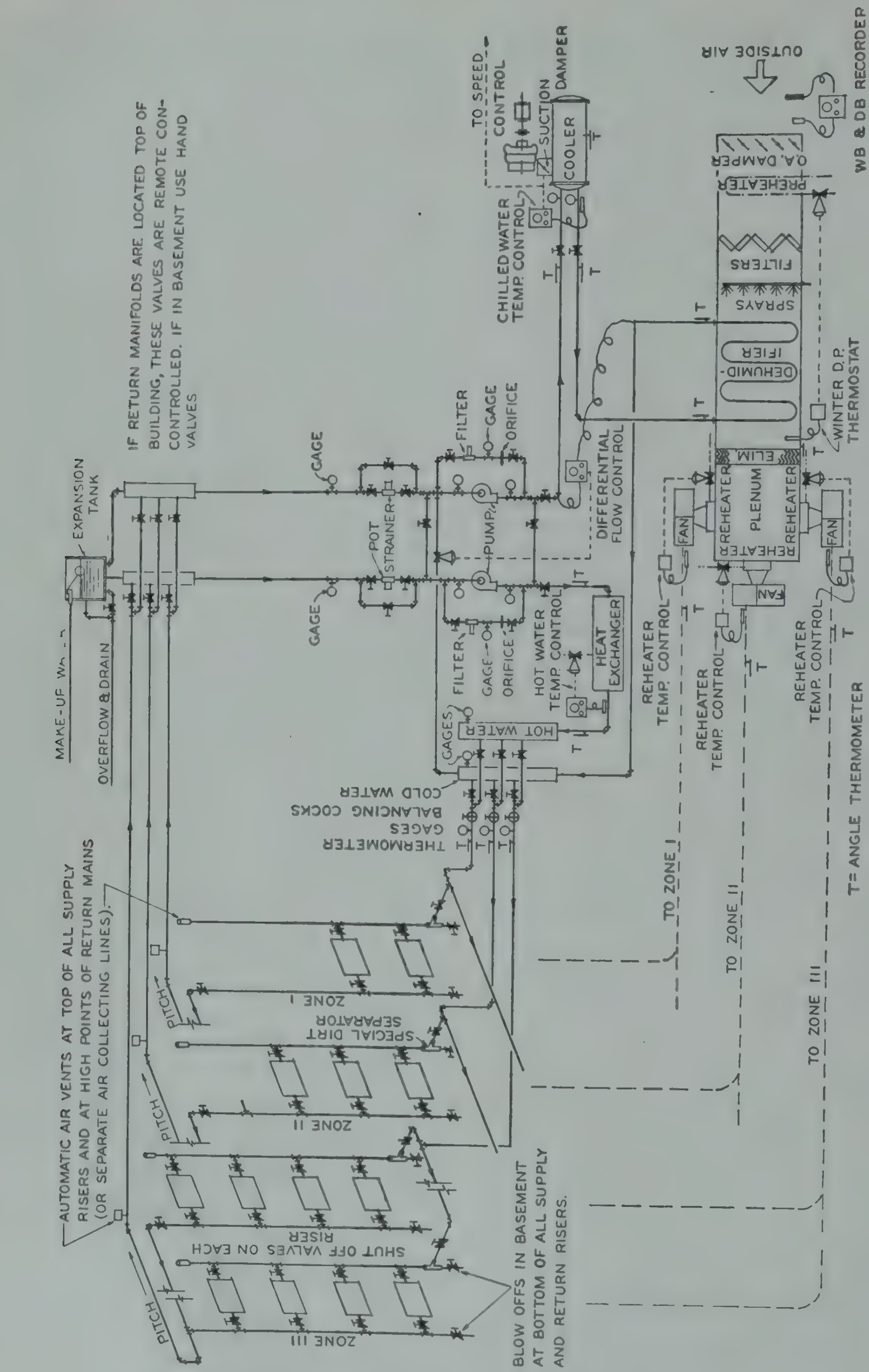

IF RETURN MANIFOLDS ARE LOCATED TOP OF BUILDING, THESE VALVES ARE REMOTE CONTROLLED. IF IN BASEMENT USE HAND VALVES
EXPANSION TANK
MAKE-UP WA...
OVERFLOW & DRAIN
GAGE
GAGE
POT STRAINER
FILTER
GAGE
ORIFICE
PUMP
FILTER
GAGE
ORIFICE
HOT WATER TEMP. CONTROL
HEAT EXCHANGER
HOT WATER
GAGES
COLD WATER
BALANCING COCKS
GAGES
THERMOMETER
DIFFERENTIAL FLOW CONTROL
CHILLED WATER TEMP. CONTROL
TO SPEED CONTROL
SUCTION DAMPER
COOLER
OUTSIDE AIR
O.A. DAMPER
PREHEATER
FILTERS
SPRAYS
DEHUMIDIFIER
ELIM.
PLENUM
REHEATER
REHEATER
REHEATER
FAN
FAN
FAN
WINTER D.P. THERMOSTAT
WB & DB RECORDER
REHEATER TEMP. CONTROL
REHEATER TEMP. CONTROL
REHEATER TEMP. CONTROL
TO ZONE I
TO ZONE II
TO ZONE III
T= ANGLE THERMOMETER
AUTOMATIC AIR VENTS AT TOP OF ALL SUPPLY RISERS AND AT HIGH POINTS OF RETURN MAINS (OR SEPARATE AIR COLLECTING LINES).
PITCH
PITCH
PITCH
PITCH
ZONE I
SPECIAL DIRT SEPARATOR
ZONE II
SHUT OFF VALVES ON EACH RISER
ZONE III
BLOW OFFS IN BASEMENT AT BOTTOM OF ALL SUPPLY AND RETURN RISERS.

Fig. 7.

problem of rising dew point as the cooling capacity is reduced.

B. Primary-Air-Unit Systems. Two types of systems employing this principle are now in use:

a. Primary air-fan-coil units
b. Primary air induction units

These systems employ room units which include coils for cooling or heating the recirculated air stream. Chilled water is supplied from a central water cooling plant for summer operation and the coil in each unit does only sensible cooling. Therefore simple throttling control of the water flow may be used without disturbing the room humidity. In winter the water piping system distributes warm water to the coils.

Filters for the return air may or may not be used with such units. The cost of filter maintenance may be excessive and a simpler method of coil cleaning is frequently adapted.

A separate system of ducts or conduits distributes primary air which is supplied from one or more central conditioners. The primary air is generally all outside air and the amount is usually only the quantity required to give proper ventilation. The primary air is cleaned and dehumidified in the central apparatus and may be reheated under some operating conditions for control purposes. In winter the primary air is humidified as required and distributed at a temperature below that of the room.

The primary air may be discharged into the room through a separate outlet or it may be introduced into the room unit.

Since the primary air quantity is constant and not controlled locally, the distribution system is very stable and duct velocities somewhat higher than normal may be used. This, coupled with the fact that only 20 to 30% of the normal air quantity required in a conventional system is circulated, means that duct sizes are greatly reduced permitting a small, vertical, distribution system.

Figure 7 illustrates the equipment arrangement and water piping system. For summer operation chilled water is circulated to the primary air dehumidifiers and after taking a temperature rise, passes in series to the room units where it performs the sensible cooling. For winter operation the circulating water is directed through a central water heater where it is heated to a temperature consistent with the load requirements on the zone. A reverse return water piping system is employed to assure balanced water supply to each of the unit coils.

Since only sensible cooling is done in the room, the coils in the unit normally operate in a dry condition, thereby minimizing problems of dirt, lint accumulation and room odors.

One of the major advantages of those systems which employ chilled water for handling the sensible cooling load is the considerable reduction in space requirements which would otherwise be necessary for equipment and duct space. This feature is of considerable importance in the application of air conditioning to tall buildings.

These systems uniquely fulfill the requirements of multi-room buildings for air conditioning. They provide:

1. Inherent individual room control
2. Ability to alternately heat or cool when required
3. Minimum of floor space and head room requirements
4. Constant ventilation and humidity control.

The under-window unit location provides excellent heating for all climates.

These systems are not quite as well adapted for partial or progressive installation as the ventilating type units.

As compared to the multiple zone or central station type of system they possess the important advantages cited above. However they introduce a much smaller quantity of air to the room and therefore do not provide as much flushing action and may require the operation of refrigeration equipment in intermediate seasons when the central duct system could provide some cooling with outside air.

A further description of the two most common systems of this type is as follows:

1. Primary Air-Fan-Coil Unit System. This system employs a unit similar to the ventilating type previously described except that the ventilation connection is

omitted. Filters are optional. The single coil in the unit performs sensible cooling only in the summer season, and can be controlled by throttling water flow. The primary air may be admitted to the room through an outlet or diffuser suitably positioned overhead or in the side wall, or optionally may be discharged into the room unit to mix with the recirculated air.

Since the primary air quantity admitted to each room is constant, higher air velocities are feasible.

Normally the fans for such units are on a separate wiring system to permit the system to be shut down or started up from a central point. Either direct driven or belt driven fans may be employed.

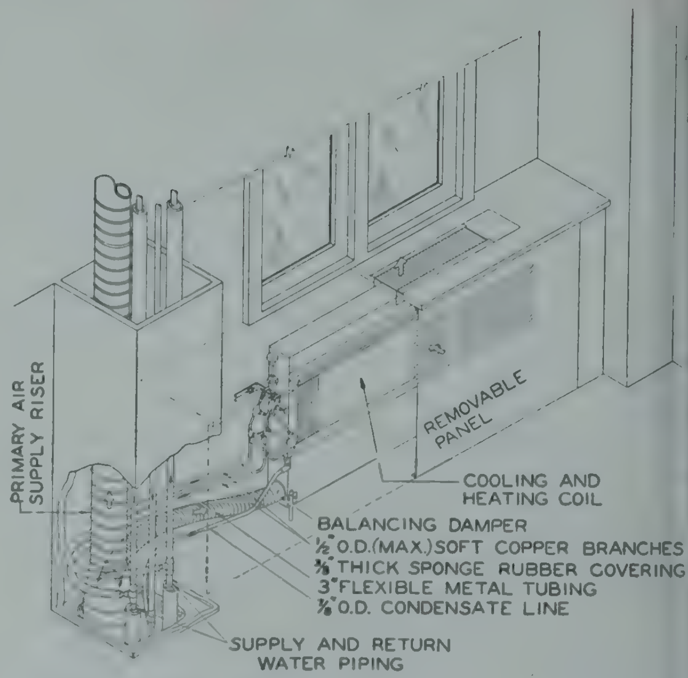


Fig. 8. Pictorial View of Furred-In Weathermaster.

2. Primary Air Induction Unit System. This system is generally known as the "Conduit Weathermaster" System. It is similar in many respects to the primary air-fan-coil system previously described but with several important differences. The room unit includes a coil in the return air for cooling or heating. The primary air is delivered to the unit under a relatively high pressure (approximately 1″ wg) and is discharged within the unit through nozzles which induce the flow of room air over the coil by means of the ejector principle.

The air quantity delivered to each room is constant under all conditions of operation and because of the special silencing provisions taken in the system, and the stability resulting from the high nozzle pressure, it is possible to distribute the air at velocities considerably higher than normal practice (3,000 to 4,000 fpm). The high distribution velocity coupled with the reduced air quantities permits distributing through small conduits 3″ to 8″ in diameter.

The primary air discharged in the unit serves three functions:

A. Provides a constant supply of ventilation air to the room
B. Maintains the room relative humidity summer and winter by means of central dew point control at the primary air apparatus
C. Provides the motive power for circulating room air over the water coil. This takes the place of the fan in the corresponding fan-coil system.

Figure 8 illustrates a typical installation of the room unit showing the cooling coil and water and air connections. In addition, although normally the coil performs only sensible cooling, an emergency condensate drain is provided to allow for unusual conditions of operation such as sudden pull-down, open windows, etc.

The supply services consisting of the primary air riser and the supply and return water piping are usually enclosed in a chase provided on the outside wall of the building.

If you searched this chapter for something which was not found in it, please let the editors know.

66. THEATRES

THE basic calculations required for the design of an air conditioning system for theatres, auditoriums, assembly halls, and similar types of buildings where the ratio of room sensible heat gain to total heat gain is relatively low, may be standardized more readily and with a greater degree of accuracy than for most other types of application. This is due, in part, to data gathered from the large number of installations in operation from which were evolved certain basic requirements with respect to heat gains, arrangement of equipment and methods of air distribution. Few buildings are comparable to theatres in their close conformity of load to number of occupants.

Because of the very nature of a theatre structure, with irregular walls several stories high and attic space, lobby, foyer, stage and other irregular forms of construction, a great amount of engineering care and time would be required if the conventional methods of heat gain calculations were always necessary. A standardized method for determining equipment sizes, based largely upon number of occupants, has proved to be practical. A method of this kind materially simplifies computations and has been used for the design of a large number of installations.

Otto W. Armspach, Author Chapter 66. Born 1/4/94 in Dowagiac, Michigan. Educated at Armour Inst. of Technology, Chicago, BS, 1917. Formerly with Drafting Dept., Amer. Blower Co., Detroit, Mich., 1916–17; plan examiner and research engineer, Ventilation Div., Chicago Dept. of Health, 1917–19; engrg. staff of ASHVE Research Laboratory, U.S. Bur. of Mines, Pittsburgh, Pa., 1919–23; E. Vernon Hill Company, Consulting Engrs., Chicago, 1924–28; mech. engr., Brunswick-Kroeschell Co., Chicago, 1928–30; chief engr., Theatre Division, Carrier Corp., New York, 1930–32; vice president and chief engr., Kroeschell Engrg. Co., Chicago, 1933–40; established own consulting practice, Chicago, 1941–44; district chief engr., Carrier Corp., New York, N.Y., 1945 to date.

Author of articles in ASHVE Transactions; series of articles on theatre comfort in the *Aerologist*, 1924–26; "Designing and Laying Out Air Conditioning Systems" published by Heating, Piping and Air Cond. Contractors Natl. Assn., 1933; Chapter 61, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Heat. and Vent. Engrs.

At present, District Chief Engineer, Carrier Corp., New York, N.Y.

General Requirements

In general, the design of the system is determined, not so much by the type of theatre, as by its size and by the location of the apparatus. A number of basic elements of design must be embodied in all installations irrespective of size of architectural features. For example, a house with a small number of seats may present a choice among several methods of introducing the conditioned air into the auditorium. Also, some variation in the volume of air circulated is permissible. But these variations in design should not be permitted to affect materially the maintained conditions of temperature, humidity and air movement. Such factors as prevention of odors, avoidance of drafts, warm spots, cold spots, noise, warm or cold air entering doors, and possibly most serious of all, over-cooling, depend almost wholly on the attention given to the basic design rather than on a so-called type of system.

Inside Design Conditions

The inside dry bulb temperature and relative humidity must be selected with special care because of the high latent heat gain as compared to that encountered in rooms with other types of occupancy. Whereas a relative humidity of 45 percent or even lower may be maintained economically in offices and similar rooms, such a low humidity in a fully occupied auditorium is difficult and more costly to maintain because of the low room sensible heat ratio. Hence, it is desirable to select that inside dry bulb temperature which, in combination with an economically practical relative humidity, will result in an effective temperature within the comfort zone.

It should be emphasized that humidities below 50 percent in fully occupied theatres require comparatively low refrigerant temperatures (see **Fig. 4**) with a corresponding

Table 1. Desirable Inside Conditions for Various Outside Temperatures for Theatres and Assembly Halls

Outside dry bulb, °F	Inside conditions: Dry bulb, °F	Rh, percent	Effective temperature, °F	Saturation temperature at apparatus, °F
100	80	55	74.5	53.2
	79	55	74	53.6
	78	55	73.5	53.6
95	80	55	74.5	53.2
	79	55	74	53.6
	78	55	73.5	53.6
	79	55	74	53.6
90	78	55	73.5	53.6
	77	55	72	53.4
	78	55	73.5	53.6
85	77	55	72	53.4
	76	55	71.5	53.1
	77	55	72	53.4
80	76	55	71.5	53.1
	75	55	70.5	52.7
	75	55	70.5	52.7
75	74	55	70	52.3
	73	55	69	51.6

increase in cost of the equipment required. Fortunately, these low humidities are not necessary for comfort. However, a humidity of 55 percent should be considered as the upper acceptable design limit. Conditions above this will accentuate odors and are not recommended.

The conditions as given in **Table 1** have been applied successfully in a large number of installations and may be used as a basis for the design and guarantee of the system.

Outside Air

The minimum amount of outside air taken into the system is that quantity necessary to prevent any noticeable odor upon first entering the theatre from outdoors, and to obtain an appreciable movement of air outward through the entrance and exit doors. This amount is independent of the total air handled.

In cases where smoking is permitted, an increased amount of outside air must be provided for in the design. Smoking is usually restricted to definite zones, for example, the mezzanine. Good practice then calls for a separate exhaust system with exhaust openings located above and as near as possible to the sources of smoke. It is also desirable to locate these openings with a view to reducing the concentration of smoke in the path of light rays extending from the projection booth to the picture screen. If a separate smoke exhaust fan is not used, a haze is likely to fill the upper part of the house, thereby requiring a greater amount of outside air. The volume of air exhausted from the mezzanine plus the air returned from the same area is in excess of the air supplied to the mezzanine, and this difference in volume will come into the smoking zone from the auditorium proper. To the basic outside air required to prevent odors, and to assure exfiltration, must be added the capacity of the smoke exhaust system to obtain the total minimum outside air.

The minimum requirements for summer operation should not be confused with the outside air needed in the winter season. The latter may be somewhat greater because of the greater temperature difference between inside and outside air and the increased chimney effect of the high auditorium. It is essential to good winter operation that an inward movement of cold air through lobbies be prevented. The result of movement in the wrong direction is a cold and drafty condition at the rear of the orchestra floor.

The following summary gives the **outside air** required for various conditions of operation:

1. The minimum quantity of outside air recommended during summer months, with smoking prohibited, is about 6¼ cfm per seat, plus standees. This value may be used to determine the refrigeration load imposed by the outdoor air.

2. For winter operation a value of 10 cfm outside air is recommended to determine the required size of the tempering heater.

3. A design based on 15 cfm outside air per seat plus standees in the zone where smoking is permitted is the minimum recommended for both winter and summer. Where there is reason to believe that smok-

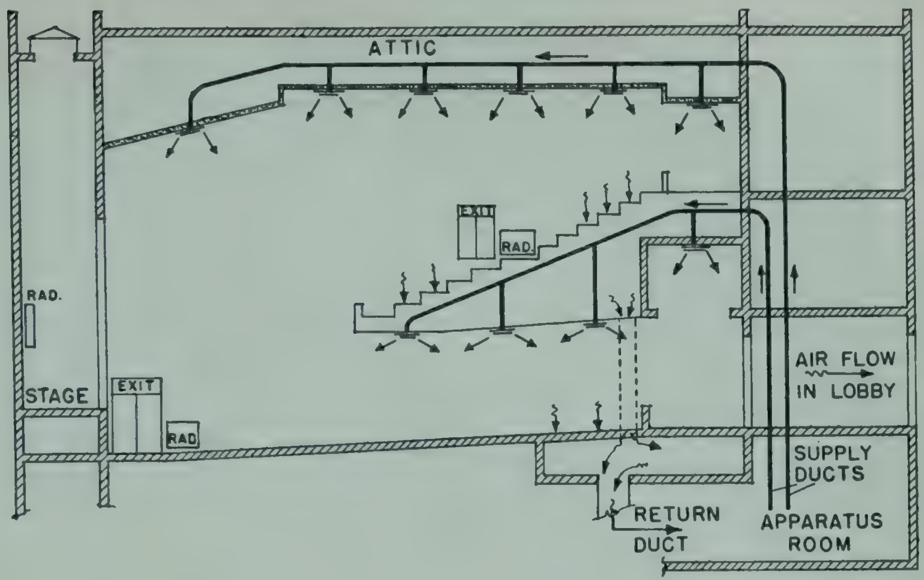


Fig. 1. Downward Diffusion System of Air Circulation.

ing will be extensive then this minimum outdoor air requirement should be increased.

Air Circulation

Systems to circulate the conditioned air throughout the theatre may be broadly placed into two general classes. One is known as the **downward diffusion system.** The air is introduced through a number of supply openings located in the ceiling of the auditorium and in soffits of mezzanines and balconies as shown schematically in **Fig. 1.** Plaques or deflecting plates are suspended below the openings to obtain a horizontal discharge of the air as it enters the room and forms a blanket near the ceiling. This layer of conditioned air, at more or less uniform temperature, then slowly travels downward into the occupied zone. This type of outlet has little induction effect and therefore the difference in temperature between entering and room air should ordinarily be kept below 15 F. The vaned ceiling outlet may also be used with the downward diffusion method of distribution. Here the air is discharged fan-wise in all directions by means of concentric deflecting vanes built into the outlet. Some induction of secondary air is obtained and an entering air temperature somewhat lower than for the suspended plaque is permissible. Ceiling outlets are frequently combined with lighting fixtures. The arrangement is particularly useful on mezzanines and other spaces where the ceiling is low.

Another method of obtaining proper distribution, and one which has been used with success in a number of theatres, is known as the **horizontal diffusion system (Fig. 2).** Air is introduced horizontally, at relatively high velocity in the rear and across the entire width of the auditorium. High velocity ejector nozzles are used to bring into circulation a large volume of secondary air. The effect of this high velocity discharge is to cause a movement of air from rear to front in the upper level and from front to rear in the lower level or breathing zone. The temperature of the primary air within the nozzle can be at least 20 F below room temperature. There will be ample air movement in the occupied area even though the total air supply has been reduced, because of the induced circulation of secondary air.

The distinctive features of the horizontal diffusion system are the lower temperature of the air supplied and the smaller volume of total air handled by the equipment. Obviously, the refrigeration load is not reduced because the amount of outside air circulated is not changed and the total of the room and outside air loads remains the same. The system is particularly applicable in the relatively small, long and narrow house. It is essential with this type of distribution that there be no interference with the movement of air throughout its

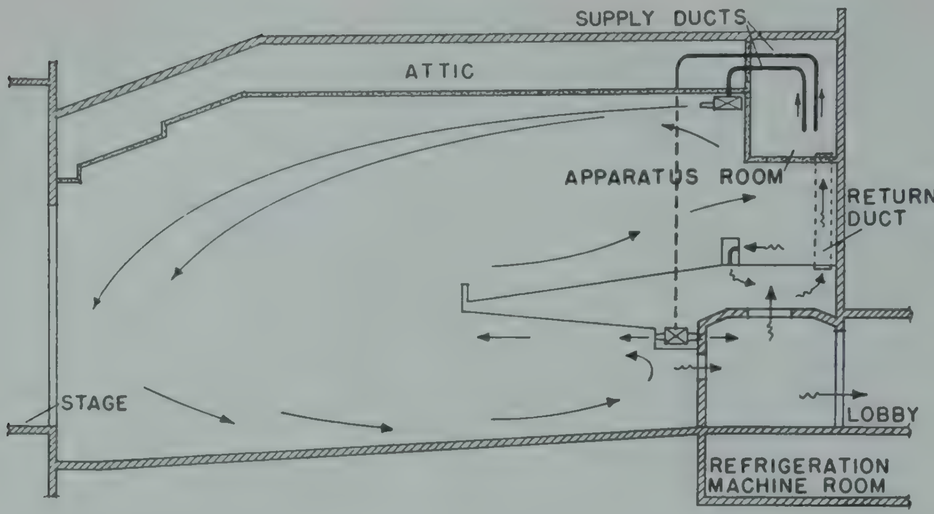


Fig. 2. Horizontal Diffusion System of Air Circulation.

entire path from the high velocity nozzles to the front of the house. The ceiling should be smooth without projecting beams or obstructing ornamentation.

Small and medium size houses have been successfully handled by side wall distribution which is a form of the downward diffusion system. Air supply outlets, carefully selected with respect to blow (guarding against over-blow), may be located in one side wall. These should be as high as possible with double deflecting vanes to promote rapid diffusion into a layer of conditioned air well above the occupied zone. The wider houses may require outlets in both side walls and possibly "staggered" with respect to the two sides.

Small theatres (less than about 700 seats) may also be handled by front wall distribution. High wall outlets are installed on either side of the proscenium arch with a blow from front to rear. Such a method of distribution can produce acceptable results providing the outlets are at an adequate distance above the floor and providing the auditorium is not so long as to require excessive grille velocities to carry to the rear. Special attention to the prevention of objectionable noise is called for inasmuch as the grilles are in the same general direction as the sound emanating from the screen.

A fundamental object of all methods of air circulation is to maintain **uniform conditions** in the **breathing zone** throughout the entire auditorium. There are a number of natural and troublesome tendencies always present in theatres, and a deliberate effort should be made in the design of the complete system to overcome them. One is toward over-cooling at the front of the orchestra floor. Another is inadequate cooling in the rear of the balcony and beneath the balcony. These tendencies are present during the heating season as well as the cooling season and they should be controlled by careful attention to the design of the supply system.

It is not considered practical to depend upon any part of the return system for maintaining uniform temperatures. Conditions can be maintained only by an adequate volume of the air introduced at the required temperature and moisture content. Upon this basis return air is merely a means of reducing the heating and cooling loads by decreasing the amount of outside air handled and of obtaining the proper temperature at the supply openings. The locations of the return air openings are of secondary importance as far as maintaining distribution is concerned. This does not mean that return air in any quantity can be removed through a single opening too near an occupant; this procedure would cause a complaint of draft.

There are a number of reasons why the front of the main floor may be cold during the heating season. The condition is frequently caused by infiltration through the exit doors located in the auditorium near the stage. It may also be caused by a cold

tum of air passing downward over the stage wall and deflected horizontally vard by the stage floor. An attempt to edy either of these difficulties by rais- the temperature of the air supplied to front usually meets with failure and ves only to overheat the rear zones fur- r. The condition can be effectively cor- ted by use of adequate direct radiation r all exit doors and on the rear stage ll, if this wall is exposed to outdoor tem- atures. Radiation in the orchestra pit is netimes advisable to counteract the flow m the stage. Another location requir- direct radiation is the entrance lobby. re, even though ample outside air is ken into the system, strong winds occa- nally cause an inward air movement at e lobby doors to upset distribution. Re- ssed radiators, convectors or concealed it heaters installed close to the points of ld air entrance successfully solve this oblem. During the summer months an er-cooled front area may usually be pre- nted by closing all stage doors and by aking certain that the vent and skylights the stage roof are tightly closed and free om air leakage. Even a slight amount of akage on the stage may cause bulging of e curtain and an objectionable forward ovement of the air in the auditorium.

Exhaust Systems

In general, the use of exhaust air systems n auditoriums should be avoided. There re two reasons: (1) Air exhausted and ot returned must be balanced in like mount by an increase in outside air above he minimum required to maintain exfil- ration, with an unjustified increase in ooling and heating loads; and (2) if the volume of outside air is not increased by he amount of exhaust, the rear of the or- hestra floor will be too warm in summer and too cold in winter. One of the indica- ions of a well designed and well balanced system is a movement of air from the rear of the auditorium through the foyer and lobby and onto the sidewalk. This effect is difficult to obtain if air is exhausted me- chanically from either the auditorium, foyer, or lobby.

Provision should be made to maintain an adequate exhaust in toilets and rest rooms. Good practice is to supply conditioned air into the rest room, with no return, in order to insure air movement in the proper direction.

An exhaust fan is desirable for spaces where smoking is permitted. This requirement is more common in theatres abroad than in the American theatre.

Another space which should be handled with a separate exhaust air system is the projection room. Each projection machine is usually connected to such a system. Exhaust openings are also desirable near the ceiling above the machines and these may be connected to the same fan providing all branch ducts are dampered. Conditioned air from the central system should be supplied to the projection room.

Because of the exhaust which is required in these miscellaneous rooms and because of the necessity of maintaining at all times an air movement through the entrance doors it is seldom necessary to provide for additional means of relieving air, except for the larger houses. A return air fan may at times be necessary in the large theatre if, because of restricted space or long duct connections, the resistance in the return air duct is unusually high. The pressure loss in the return should approximately equal the loss through the air intake and tempering heater to obtain proper balance of the system. The return fan should be arranged to discharge outdoors when 100 percent outside air is used, and no additional provisions for relieving air are necessary.

Location of Apparatus

In existing buildings the designer may have little choice in the location of various pieces of equipment. In new buildings, however, weight of apparatus, accessibility, noise, vibration and type of distribution are some of the factors that should be given consideration when selecting the apparatus room. The location and arrangement materially affect not only the first cost but the operating cost as well. Obviously, long connections between the central air handling equipment and the points of air introduction may require duct insulation which could otherwise be omitted. On the other hand, when the supply fan is only a short

distance from a supply opening, the elimination of noise becomes the major problem. Sound absorbers in the fan discharge, acoustical lining, wrapping of ducts, and isolated foundations and supports may be necessary.

The most desirable location is shown in Fig. 2. Here the apparatus room is beside the projection booth. Air is supplied to the mezzanine and a large part of the orchestra floor through a duct extending directly from the fan to the attic space with branches to the various ceiling openings. No duct insulation is ordinarily required and the minimum amount of material for sound absorption will prevent objectionable noise from being heard in the occupied zones. A comparatively short branch duct is carried into the mezzanine structure to supply the occupants on the main floor rear. Proper distribution is obtained without an extensive return air system. The refrigeration plant is located in the basement under the lobby where there is little likelihood that its operation will be heard in the auditorium. If space is not available for the apparatus at the upper rear of the theatre it may be installed to advantage beside the refrigeration equipment in the basement (Fig. 1). In this case only slightly more ductwork is required and this is partly offset by the shorter refrigerant or cold water lines extending to the dehumidifier.

On occasions a room under the stage may be the only available space for equipment. This is probably the least desirable location for a number of reasons. First, every precaution must be taken so that apparatus noise does not interfere with the operation of the sound equipment; usually, soundproofing of the room is necessary, since vibrations transmitted to the sound devices on the stage must be prevented. Another reason for avoiding this location is the long duct required to reach the supply openings in the mezzanine soffit. An excessive rise in temperature of the air within the duct, because of its added length, may make it impossible to maintain satisfactory conditions in the rear of the main floor. Furthermore, lack of sufficient air because of added frictional resistance can also aggravate this condition. It is well to keep in mind that this zone under the m zanine is one of the areas which tend to come overheated.

Small and medium size theatres are u ally handled with one supply system. I the large house, consideration may given to the use of two individual sup systems, one for the main floor and a other for the balcony. The lobby, foyer a miscellaneous rooms should be suppl from the main floor unit although a se rate lobby fan is sometimes desirable. Th greater flexibility in operation is possib If air, at the same temperature as is su plied to the fully occupied orchestra flo is also sent to the balcony which may ha few occupants, then a layer of cold air m slide off the balcony onto the audience b low. This cascade can be avoided by separate balcony unit under independe temperature control.

The accessibility of equipment and ea of operation and maintenance are close related to the location of the apparat room. A poor location can only result improper maintenance and expensive a time-consuming repairs. Obviously, t ideal location is not always made availab in existing houses, but equipment rooms remote attic areas, accessible only by mea of long ladders, and other equally inco venient spaces should be rejected witho hesitation.

Good operation and maintenance faci ties also demand that ample space be a lowed for cleaning and removing coi cleaning or replacing of filters and strai ers and removal of dirt from air wash pans, and cleaning of nozzles. Floor drai in the outdoor air plenum and betwe eliminators and fan not only guard again water damage to ceilings below but also en able proper cleaning of these chamber Also, excellent incentives to good mai tenance and operation are properly locate thermometers and gauges, where possib at eye level and adequately sized acce doors. It is advisable to provide lights i air washers and in all chambers.

The entire distribution system should b critically examined to determine the su faces which should be insulated. The ten perature rise in the long branches should b calculated and insulation applied to elim

e an excessive rise. Omitting insulation attic ducts in order to lower the first t frequently results in an unjustified in-ase in operating cost and wide tempera-e variations throughout the seating as. It is recommended that the surfaces ll ducts supplying the rear of the house ich are located within the attic space be ulated. Ordinarily it is not necessary to ulate ducts in balcony or mezzanine uctures nor the relatively short runs in sements.

Arrangement of Apparatus

The apparatus should be capable of per-rming all functions of a year-round air nditioning system. The essential com-nents of such an installation are multi-e outside air dampers, fan, preheater, eans for cleaning the air, dehumidifier, heater, bypass, automatic control de-ces and supply and return air distribut-g systems. All of the available methods r removing moisture and cooling air are pplicable to obtain the necessary dehu-idifying effect, and various types of the regoing components may be used.

A typical apparatus arrangement is hown diagrammatically in **Fig. 3.** Outside ir is obtained through screen-covered eather louvres in the wall of the appara-us room. The automatic intake damper eally consists of three individual dampers. No. 1 opens upon starting the fan to ad-nit the minimum design quantity of out-ide air. Damper No. 2 may be opened by neans of a manual device to increase the ninimum quantity for winter operation, nd the time when it is used is somewhat letermined by wind characteristics. By pening the third intake damper and clos-ng the return, the full volume of outside ir can be circulated to obtain maximum enefit from a favorable outdoors condi-ion. The tempering heater is located in the ir stream from dampers No. 1 and No. 2.

The dehumidifier shown is a water spray type, although direct expansion or water coils may be substituted without funda-mentally changing the design. The re-heater is located beside the dehumidifier because of the limited length of the room. The damper controlling the amount of air through the reheater is placed in a converg-

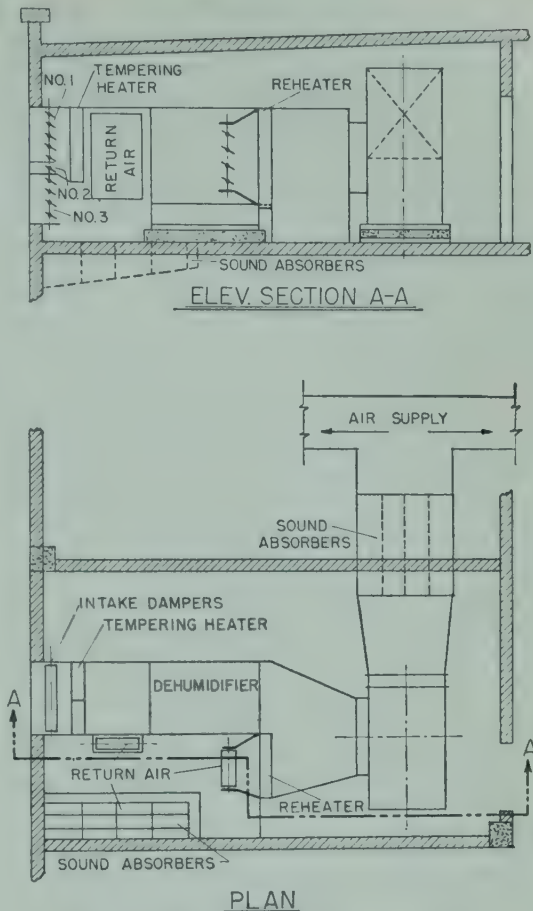


Fig. 3. Typical Apparatus Arrangement.

ing collar on the inlet side, thus reducing its size and accomplishing a smoother and more sensitive control action. Many in-stallations have also been made with a by-pass above the dehumidifier and ahead of the reheater. Space conditions largely dic-tate the best arrangement. Return air comes through the floor of the room. Many installations require that sound absorbers be placed in this return opening. Similar absorbers are usually considered necessary in the fan discharge duct as shown.

Air Required

The capacity of the air handling equip-ment is a direct function of the number of seats plus standees. Also, the **total air cir-culated** by the fan **per occupant** is deter-mined by the type of air distributing sys-tem, the horizontal diffusion system requir-ing the minimum of primary air because of its induction effect. Occasionally, munici-

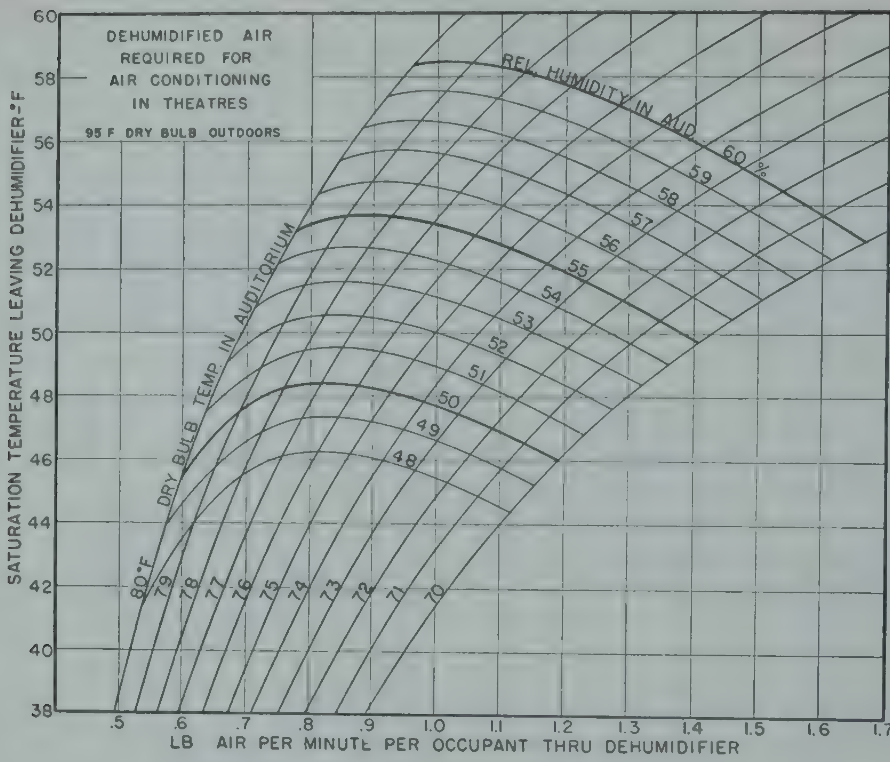


Fig. 4. Apparatus Temperature Required in Theatres.

pal codes fix the volume of air per occupant. But it should be kept in mind that, regardless of the total volume, the quantity required from the dehumidifier and the temperature and moisture content of the dehumidifier are definitely established by the temperature and relative humidity to be maintained. The refrigeration capacity is not affected by the total air circulated unless the quantity of outside air is changed.

Downward diffusion systems require about 25 cfm per occupant. The largest and most luxurious theatre in the United States was designed to circulate 27 cfm per occupant. Other installations have used as high as 30 cfm. An increase in the amount of total circulation will decrease the spread between room and incoming air temperatures. This temperature spread is a factor closely related to the problem of drafts. If the air circulated is increased from 25 to 30 cfm there will be an increase of approximately 2 F in the temperature of the supply air. But with the smaller volume the difference in temperature between incoming air and room is only about 13 F. This differential is not considered excessive and there is little danger of a draft due to too low entering air temperature. On the other hand, when supplying the higher quantity of air, conditions may be even more drafty than before, because there will be an increase of 15 percent in the velocity of the air passing over the audience. For this reason, it is well to place emphasis on the location and the number of points of air introduction. The best results can be obtained by selecting an ample number of supply openings of relatively small capacity rather than by obtaining a reduction in first cost by use of too few openings. When air is admitted in excessive volume through any one opening, distribution is impaired and unsatisfactory conditions may result, irrespective of the temperature of this air.

One of the advantages of the horizontal diffusion method of distribution is the practicability of using smaller total air volumes. This, of course, reduces the size of the intake, fan, and ducts with a reduction

Table 2. Average Sensible Heat Ratios for Theatres and Assembly Halls

Room dry bulb, °F	Sensible heat ratio, percent
80	64.0
78	67.0
76	70.0
74	73.0
72	75.0

n the first cost of the plant. Obviously, the ize of the dehumidifier is not changed, because, for a given load and room condition, here is no change in the volume and temperature of the dehumidified air required. These systems have given good results when based on 15 to 18 cfm per occupant.

The temperature and humidity for which the plant is designed, together with the rate at which room sensible and latent heat must be absorbed, determine the quantity and condition of the air leaving the dehumidifier. The room heat load is usually expressed as a sensible heat ratio. (See Chap. 37, 1949 Basic Volume, ASRE Data Books.) A number of psychrometric charts now include a scale of sensible heat factors which facilitate the determination of the required entering conditions.

A correct determination of the **apparatus dew point** is one of the most important steps in the design of a system for theatres. This temperature not only fixes the quantity of dehumidified air, but it also determines the temperature of the cooling medium. Unless the apparatus dew point temperature is accurately predetermined the guarantee of room relative humidity becomes hazardous. Also, because of the unusually heavy latent heat load in a fully occupied theatre, the apparatus dew point must be lower for a given room relative humidity than for most other applications. One of the most common causes of failure to meet a humidity guarantee is the failure to appreciate fully that these low temperatures are necessary. Hence, it is of assistance to observe on a single chart all dew point temperatures required for various room conditions. Such a chart is shown in **Fig. 4.** Note that to maintain a temperature of 80 F with a humidity of 55 percent requires a saturation temperature of 53.2 F, but to maintain 50 percent humidity it is necessary to lower this temperature to 45.6 F. This emphasizes the difficulty of holding low humidities in a fully occupied house. The chart gives the apparatus temperature based on 100 percent saturation efficiency. For dehumidifiers which do not fully saturate the air as, for example, surface coils, the leaving conditions determined from this chart may be adjusted by use of the sensible heat ratio curves on the psychrometric chart and the factors given in **Table 2.**

Equipment Sizes

The sizes of the various parts of the system may be conveniently determined on the basis of cfm per seat plus standees. **Table 3** for downward diffusion systems and **Table 4** for horizontal diffusion systems have been extensively used for determining equipment sizes.

Cooling Load

A calculation of the cooling load in theatres must include the following sources of heat:

1. Heat from lights
2. Heat transfer through building construction
3. Heat from occupants
4. Heat in the outside air circulated by the system.

Of these four heat sources only those in groups 1 and 2 vary with the construction of the building, and are not a direct function of number of occupants. Hence, the per occupant load imposed by these two groups theoretically differs in each theatre. But groups 3 and 4 are independent of building construction and are constant for a given outdoor and indoor design condition. Also a valuable aid in simplification of calculations is the fact that under maximum load conditions with 95 F dry bulb temperature outdoors, the cooling load due to heat gains in groups 3 and 4 is approximately 87 percent of the total load. As the outdoor temperature falls, the heat transfer through the construction becomes negligible. Because of these facts it is practical to determine the refrigeration load on a per occupant basis by use of a chart, and for most installations there is no need of a

Table 3. Data for Equipment Design-Downward Diffusion Systems

Air quantities: Equipment	CFM per occupant	Velocities: Locations	Maximum ft per min
Total air supplied	25	Fan outlet	1700
Small outdoor damper	$6\frac{1}{4}$	Initial duct velocity	1700
Intermediate outdoor damper	$3\frac{3}{4}$	Small outdoor damper	1000
Large outdoor damper	15	Intermediate outdoor damper	1000
Maximum outside air	25	Large outdoor damper	1000
Minimum outside air	$6\frac{1}{4}$	Outside air intake duct	1000
Through tempering heater	10	Intake louvres	890
Around tempering heater	15	Through tempering heater	800
Reconditioned air damper	14	Around tempering heater	1200
Through dehumidifier	18	Reconditioned air damper	1200
Bypass damper	$18\frac{3}{4}$	Through dehumidifier	650
Through reheater	$18\frac{3}{4}$	Bypass damper	1600
Return air	$18\frac{3}{4}$	Through reheater	900
Air relief damper	$12\frac{1}{2}$	Return air duct	1500
		Air relief damper	1500
		Return grilles	400

detailed and itemized load computation. This chart, shown in **Fig. 5,** is based on 0.462 lb of outside air per min per occupant and is applicable in all climates. The total refrigeration load is found by entering the lower scale on the left at outdoor wet bulb design temperature. By continuing on a path as indicated by the dotted line, one arrives at the total load on the tonnage scale on the right of the chart. The load may be adjusted for any increase in amount of outside air by use of the equation:

$$T = \frac{(W - 0.462)(H - h)}{200}$$

where

T = increase in tons of refrigeration
W = total outside air, lb per min
H = enthalpy of outside air, Btu per lb of dry air
h = enthalpy of inside air, Btu per lb of dry air.

(For values of enthalpy, see Chap. 10, 1949 Basic Volume.)

Table 4. Data for Equipment Design-Horizontal Diffusion Systems

Air quantities: Equipment	CFM per occupant	Velocities: Locations	Maximum ft per min
Total air supplied	18	Fan outlet	1700
Small outdoor air damper	$6\frac{1}{4}$	Initial duct velocity	1700
Intermediate outdoor damper	$3\frac{3}{4}$	Small outdoor damper	1000
Large outdoor damper	8	Intermediate outdoor damper	1000
Maximum outside air	18	Large outdoor damper	1000
Minimum outside air	$6\frac{1}{4}$	Outside air intake duct	1000
Through tempering heater	10	Intake louvres	800
Around tempering heater	8	Through tempering heater	800
Reconditioned air damper	$11\frac{3}{4}$	Around tempering heater	1200
Through dehumidifier	18	Reconditioned air damper	1500
Bypass damper	$11\frac{3}{4}$	Through dehumidifier	650
Through reheater	$11\frac{3}{4}$	Bypass damper	1200
Return air	$11\frac{3}{4}$	Through reheater	800
Air relief damper	8	Return air duct	1500
		Air relief damper	1500
		Return grilles	400

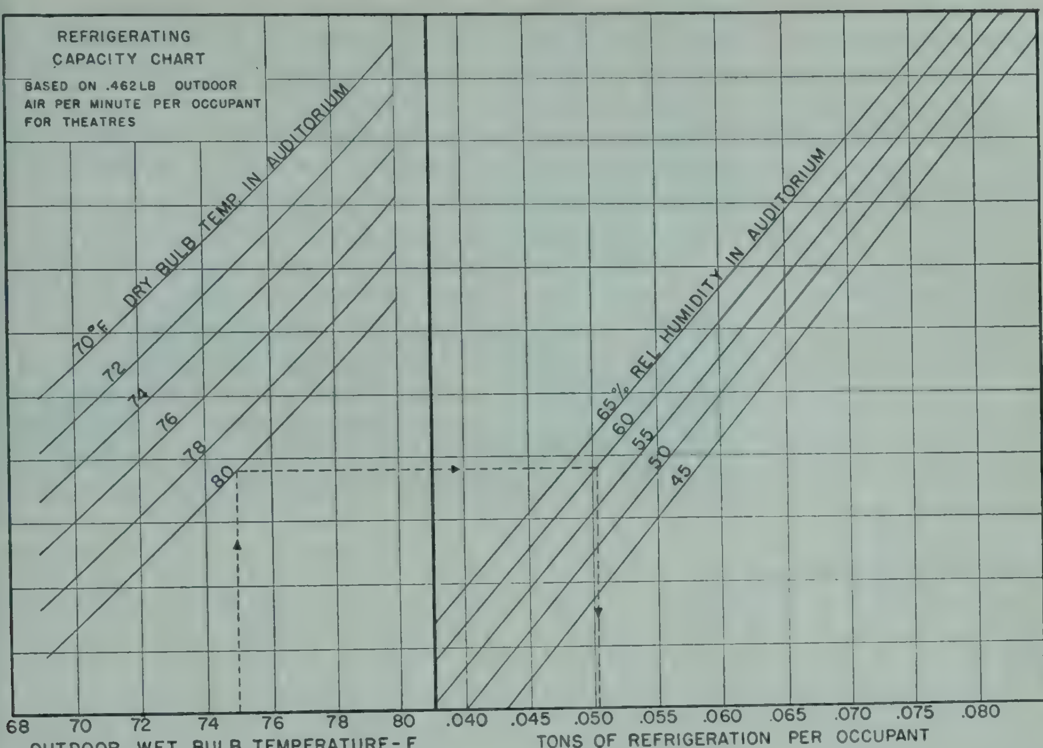


Fig. 5. Refrigeration Required in Theatres.

Refrigeration

In the selection of the system, a number of limitations with respect to kinds of refrigerant and use of direct expansion should be fully considered. These requirements, in the interest of public safety, are set forth in various codes for mechanical refrigeration and they should be carefully studied by the designer.

For the smaller houses, the reciprocating compressor with Freon-12 is usually employed. Flexibility in capacity is obtained by installing the units in multiple or by controlling the capacity of a single unit through automatic regulation; a number of practical methods to accomplish this purpose are available. The machine, with suitable refrigerant, may be arranged with direct expansion coils in the path of the air; or a separate water cooler may be used in which case chilled water is pumped to an open spray or surface coil type dehumidifier. The centrifugal machine with built-in condenser and evaporator is frequently used in the larger houses, and water chilled in the unit is commonly circulated through the dehumidifier. The capacity is adjusted to the load by regulation of the quantity of water passed through the condenser, by varying the speed of the compressor, or by means of a suction damper.

Water from wells, if available, may sometimes be used in lieu of mechanical refrigeration. It is not frequent that such water is cold enough to replace the mechanical unit entirely, but it can at times be used to reduce the size of the machine. Systems of this kind are designed with a pre-cooler through which the well water is passed before going to the condenser. Mechanical refrigeration is then applied to the second stage of the dehumidifier.

Automatic Control

The control system for theatres must not only correctly place in position all dampers, valves, and other automatic devices in the heating, cooling and intermediate season cycles, but it must also be sufficiently sensitive to respond almost instantly to all

load changes. Within a matter of minutes, the cooling requirement may vary from a negligible amount with a house practically empty to the maximum load with all seats occupied. The system should be designed with these severe demands in mind. Any of the commonly accepted arrangements of year-round control may be used. Yet some modifications are at times desirable to accommodate special requirements. The thermostat which controls room temperatures is usually placed in the return air duct at the apparatus rather than in the auditorium. This location has been found to produce a more uniform room temperature and is less subject to localized influences.

Fig. 6. High Velocity System in Small Theatre.

The control system should be designed with the following essential requirements in mind:

1. Prevent over-cooling. This is considered one of the most serious results of a poorly designed system.
2. Prevent excessive room humidities. Controls should be provided to avoid exceeding the upper acceptable design limit of 55 percent relative humidity.

To meet these two requirements it is strongly recommended that an air by-pass around the dehumidifier be used. This gives positive and simple control over room temperature and in addition permits a lowering of apparatus dew point on reduction in load. Accordingly, more desirable room humidity conditions (below the acceptable design maximum) are maintained whenever the house is partially occupied.

Banks and Monumental Buildings

In general the elements of design which apply to theatres also apply to assembly halls, monumental buildings, public spaces in banks and the like where the heat from occupants is a large part of the total load. Obviously, the office area in banks which frequently surrounds the public space should be treated as office space and the conventional methods of computing heat gains through construction should be used. Better control of the room condition is obtained by placing this office area on a zone system separate from the system handling the public space. In memorial and similar buildings the assembly hall should be placed on its own system independent of the system serving other miscellaneous rooms.

Summary of Design Precautions

The fundamental requirements of air conditioning systems for theatres can be met only by the most careful selection and coordination of all parts of the installation. In considering the details of equipment arrangement and design, it may be helpful to repeat and itemize some of the important requirements which, in large measure, determine the success of the complete plant:

1. The air distributing system should be designed to maintain a gentle air movement from front to rear at head level. Any movement in the opposite direction will usually prove objectionable.

2. At no time should air be exhausted from the lobby as this is likely to cause an inward movement through the entrance doors.

3. To counteract the chimney effect

of the building it is imperative that all openings where air might escape be tightly closed, such as cracks between the building walls and roof construction, leaky stage vents, and open exit doors, particularly on upper levels. Ventilators in the roof communicating with the attic space should not be used.

4. Direct radiation is required at all exit doors, on the stage, and in the entrances.

5. Means should be provided to take from outdoors the full capacity of the fan during the intermediate season when neither heating nor mechanical cooling is required. This period may extend over several weeks, and the simple arrangement permits a considerable reduction in cost of operation. Prior to occupancy, the intake may be entirely closed to facilitate preheating and precooling the house.

6. Carefully select the location of the apparatus room to obtain the shortest and most direct route between the supply openings and the fan discharge. If the temperature rise in the ducts feeding the rear of the house and upper balcony is too great, uniform comfort conditions cannot be maintained.

7. Locate the refrigeration equipment in the basement, if at all possible, to encourage proper maintenance and to prevent noise and vibration from reaching the auditorium.

8. Use sound treatment in the supply and return connections at the apparatus to avoid any undue increase in the noise level in the occupied zones.

9. Provide ample points of air introduction in the rear of the main floor and balconies and restrict the supply to the front. An unnecessarily large number of supply openings is much less serious than too few openings.

10. Do not depend on return openings to assist in maintaining proper distribution. However, excessive air movement in the vicinity of a return should be avoided. This condition can be caused by too large a volume being withdrawn through a single opening.

11. Analyze the need for duct insulation particularly on attic ducts supplying the rear. Attempts to offset excessive temperature rise by increased air supply in lieu of insulation is likely to produce objectionable air motion.

12. Use the air by-pass to obtain a simple means of control and to permit lower room humidities in partially filled houses.

13. Simple, positive methods of automatic control, together with sufficient gages, thermometers, and instruments for intelligent handling are considered essential for good theatre operation. Log sheets to record daily indoor and outdoor conditions of temperature, humidity, attendance and equipment performance, with detailed printed operating instructions, also tend to increase the overall plant efficiency.

If you searched this chapter for something which was not found in it, please let the editors know.

67. RESIDENCES

Heating Systems

A COMPLETE discussion of residential heating would seem out of place in a refrigeration handbook. However, the application of year 'round air conditioning, including summer cooling, to residences usually involves the addition of some form of refrigeration equipment to a more or less conventional heating system. Consequently some discussion of heating systems for residences is in order.

The source of energy for heating systems is, in almost all cases, a combustible fuel. In the case of automatic or thermostatically controlled residential heating systems, the fuel is usually either gas or oil. With the trend toward conservation of the nation's oil supply and the higher price of oil which appears inevitable because of greatly increased demand and dwindling reserves and because of the improved distribution facilities for natural gas, it seems apparent that natural gas will be not only the preferred fuel in the future but also the most economical.

Methods of transferring the heat produced by the fuel to the house vary in popularity in different areas of the country for no apparent reason. By far the most popular type of system at present, however, is the forced warm air heating system in which the heat of the fuel is transferred directly to a stream of air circulated by an electrically driven blower over a cast iron or fabricated sheet steel heat exchanger. Forced warm air furnaces usually include contact filters and a humidifier consisting of a pan which is supplied with water through a float valve or solenoid valve controlled by a humidistat. Often porous ceramic elements are inserted in the humidifier pan in such a manner that they draw water from the pan by capillary action and thereby increase the surface available for evaporating water into the air stream.

The conventional control system for forced warm air heating systems includes a room thermostat which actuates the burner, a fan switch which starts and stops the fan in response to the temperature of the air in the top or "bonnet" of the furnace and a limit switch which shuts off the burner in the event that the temperature in the top of the furnace should become excessive.

The room thermostat is normally set by the owner to obtain the desired room temperature. The fan switch cut-in point is set at as low a temperature as possible without causing objectionable drafts when the fan starts. Ordinarily the cut-in point will be in the range between 90 and 105 F depending largely on the location of critical outlets which might direct a stream of cool air on a sitting or reclining occupant. The differential between the fan cut-in and cut-out

JOHN DEB. SHEPARD, Co-Author Chapter 67. Educated at Cornell University, ME, 1929. Formerly with Carrier Corp., Newark, N.J., 1929–30; Philadelphia, Pa., 1930–34; Air Conditioning Engineer, Consolidated Gas, Electric Lt. and Pr. Co., Baltimore, Md., 1934–45; Associate, P. L. Davidson, Consulting Engineer, 1945 to date. Chairman, Amer. Gas Assn. Air Conditioning Committee; Edison Elec. Inst. Air Conditioning Committee.

Author, air conditioning section, Standard Handbook for Elec. Engrs., 7th and 8th editions; air conditioning technology, American Gas Assn.; papers presented before ASRE meetings, sectional and national; Chapter 62, 1946 Applications Volume, ASRE Data Books.

Member, Amer. Soc. of Refrig. Engrs.; ASHVE; ASME; registered professional engineer in several states.

At present, Associate, P. L. Davidson, Consulting Engineer, Greensboro, N.C.

E. P. PALMATIER, Co-Author Chapter 67. Born 7/2/11 in Newark, N.J. Educated at Stevens Inst. of Technology, ME, 1932; Harvard, MS, 1934. Formerly engaged in development and application engineering of centrifugal refrigeration machines, Carrier Corp., 1934–40; sales engineer on industrial refrigeration, New York office, 1940–42; research project engineer in charge of aircraft icing research, Propeller Div., Curtiss-Wright Corp., 1942–45; assistant to W. H. Carrier, Carrier Corp., 1945–48; project engineer, Research Dept., 1948 to date.

Author of several published articles on refrigeration, thermodynamics and psychrometrics, as well as the originator of the "enthalpy deviation" form of psychrometric chart.

Member, Amer. Soc. of Refrig. Engrs.; ASME, ASHVE, and Tau Beta Pi; Licensed professional engr. in New Jersey.

At present, Project Engineer, Carrier Corp., New York, N.Y.

point should be reduced to the lowest possible value without causing short cycling of the fan when the burner turns on during normal operation. The fan speed and balancing dampers of the system are normally adjusted to produce a temperature rise through the furnace of around 100 F. The limit switch is normally set at 200 F.

The method of setting controls for forced warm air heating systems described above results in continuous fan operation in all but mild weather and makes possible better balancing of the heating system and more uniform room temperatures throughout the residence. For further discussion of forced warm air heating systems the reader is referred to the National Warm Air Furnace Manufacturers Association Bulletins 6 and 7. Bulletin 6 discusses the setting of controls and Bulletin 7 covers the design of warm air distribution systems.

Forced warm air heating systems are the only systems to which summer cooling or air conditioning can be conveniently applied, consequently more space has been devoted here to the discussion of this type of system. However, there are two other types of residential heating systems which should receive some comment. First, is the steam or hot water heating system using individual room convectors or radiators. In this system the steam is generated or hot water is heated by a central boiler or heater whose burner is controlled either directly by the room thermostat or by the steam pressure or hot water temperature in the unit. In the case of hot water systems, if the burner is controlled by the hot water temperature, the room thermostat controls the operation of an electrically driven water circulating pump. In the few cases where the burner operation of a steam boiler is controlled by steam pressure, the room thermostat controls a motor operated valve in the steam supply line. Normally, however, steam systems utilize room thermostat control of the burner.

The steam or hot water is conducted to the room convectors or radiators which normally heat the room by a combination of natural convection and radiation.

Finally, there appears to be increasing use of radiant heating systems in residences. In the case of truly radiant heating systems, coils of pipe are embedded either in concrete floor slabs or in the plaster (usually of the ceiling). Relatively low temperature hot water is circulated through these coils; normally between 95 and 110 F. With this type of system a considerably larger portion of the heating is accomplished by direct radiation from the warm ceiling or floor to the occupants and other objects in the room than that which is accomplished by convector or radiator systems. Nevertheless, a sizable amount of heat released by the so-called radiant heating systems is actually transferred by convection. Ceiling radiant heating systems are normally preferred over floor radiant heating systems for residences because it is possible to carry a higher surface temperature and because ceiling systems exhibit less thermal lag when abrupt changes of heating load occur (for example, upon incidence of sun effects) and consequently cause less control difficulty. Also, the design of floor radiant heating systems is complicated by the uncertain degree of floor covering which will be used.

A system which combines to some extent the features of both radiant heating systems and convector heating systems is the so-called "baseboard radiant heating system." In this system heating elements of various types are located along the base of all or most of the outside walls of the house. These elements may be cast iron or prime surface or finned surface tubing covered with a sheet metal cover which simulates the baseboard. In some cases the design is such as to cause considerable convection through the element which increases the heat which can be liberated per lineal foot.

It should be obvious that of the three basic types of residential heating systems discussed (namely, forced warm air, steam or hot water convector systems, and radiant heating systems) only the first is capable of simple integration with a summer cooling or air conditioning system. Of course, it is possible that a hot water convector system could be made to produce cooling by the circulation of chilled water and by the addition of fans to the convectors. It would also be necessary to add drains to carry away moisture condensed

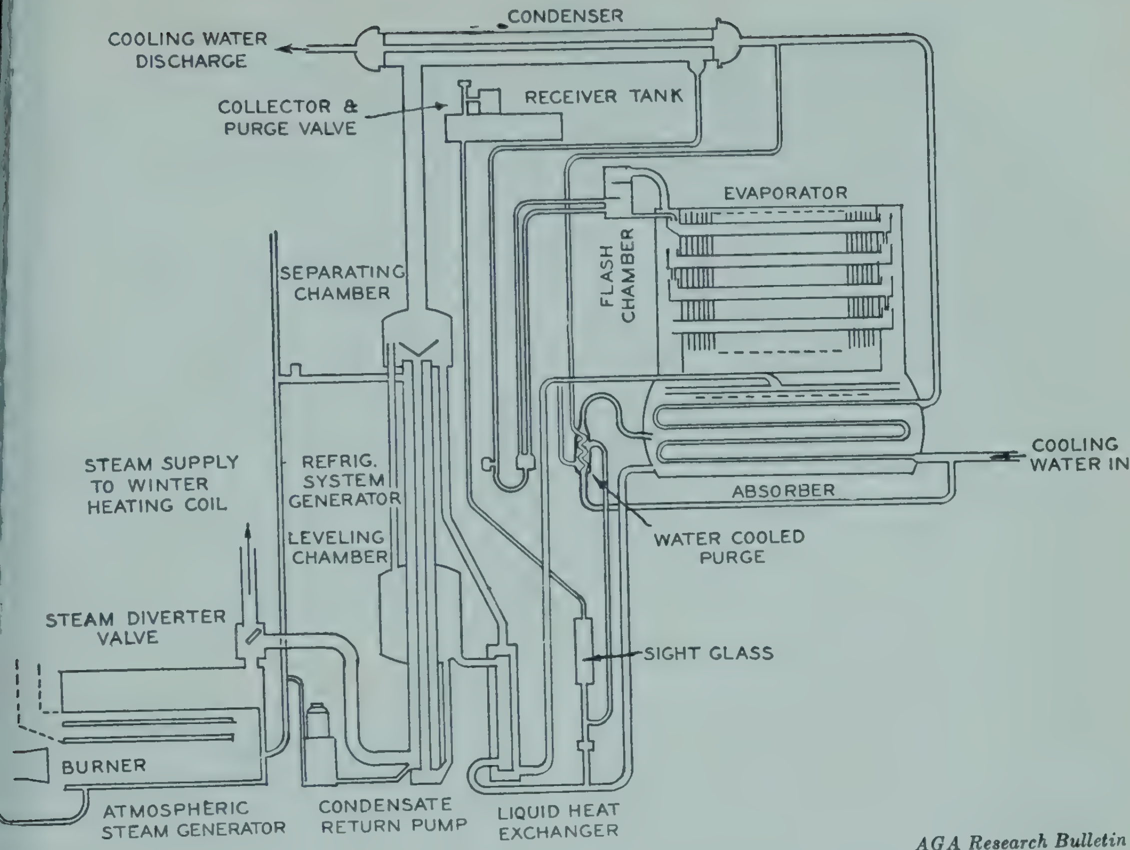


Fig. 1. Servel Gas Fired Year-Around Air Conditioning Unit.

from the air. Forced warm air heating systems, however, can be designed originally or converted to produce adequate summer air conditioning simply by the addition of a direct expansion cooling coil and refrigeration compressor located adjacent to the furnace. The cooling coil and refrigeration machine may be separate elements or they may be integrated as a complete cooling unit, with or without a separate fan.

Cooling Market

More will be said about residential cooling or air conditioning equipment later. But first, in order to develop some perspective, discussion of the residential cooling market is in order. Figures on the total number of air conditioning installations in residences, exclusive of room cooler installations, are difficult to obtain. In 1941 there were probably no more than 3,000 residences in the entire United States equipped with summer air conditioning. Since that time it is estimated that between 4,000 and 5,000 installations have been made. Of these more than half have been made within the last two years, 1948–49. New installations are being made at present at the rate of about 1,500 per year.

According to the 1940 census about 14.5 million homes had central heating systems. Of these about half were warm air systems of either the forced or gravity type. By now the total number of centrally heated residences has probably increased to 17 or 18 million of which perhaps 9 million have warm air furnaces.

It is obvious therefore that at present only about one house in a thousand equipped with warm air heating is also provided with summer cooling or air conditioning. Likewise, the annual sales of residential air conditioning units are only a tiny fraction of the sales of forced warm air furnaces.

Residential Cooling Equipment

In view of the above market situation,

air conditioning equipment manufacturers have been reluctant to invest any appreciable effort or money in air conditioning equipment which is specially designed for residences. So-called residential units in most cases have been adaptations of unitary air conditioning equipment designed for small stores and offices.* There are at least two exceptions to this statement. First, a gas fired year 'round air conditioning unit whose absorption refrigeration cycle is illustrated in **Fig. 1.** This unit provides year 'round air conditioning using steam generated in an integral gas fired boiler as the energy source. This unit is available in 3 and 5 ton cooling capacities and with heating capacities ranging from 60,000 to 180,000 Btu per hour. Several thousand of these units have been placed in service within the last five years, a portion of these have found application in commercial establishments rather than in residences.

A second exception was a special residential unit providing cooling only which was marketed experimentally immediately before the war. The unit consists of a 2½ hp condensing unit, direct expansion cooling coil, water precooling coil, fan, filters and sound absorber. Normal installation is made in the attic of the residence. The unit is designed to take all outside air which passes first through the water precooling coil, then through the direct expansion coil, after which it is delivered to the residence; usually through a single outlet. Concentration of the cooling effect is controlled by opening windows from which the air supply escapes. This controls, to some extent, the flow of air through the residence. The city water used by the unit first passes through the water pre-cooling coil and then to the refrigerant condenser. Such a unit can have fairly good performance in locations where city water is relatively cold and plentiful in summer and where outside conditions do not become too severe. Otherwise a conventional unit which recirculates the air through the cooling unit rather than taking outside air should prove much more effective and economical.

Fig. 2 shows a conventional 3 or 5 ton commercial air conditioner and two ways in which it can be applied to a residential warm air heating system. In one case the return air is allowed to pass through the basement space and into the return grille of the cooling unit. In the other case the return air is ducted through the cooling unit. In some localities existing codes would prohibit the former type of application. It has the advantage, however, of keeping the basement of the residence dry and relatively cool while at the same time adding little or no cooling load. If the basement space is not used as a return plenum either dehumidified air must be supplied from the cooling unit to the basement or the supply ducts of the equipment must be insulated to prevent objectionable condensation.

Fig. 3 shows a room air conditioner of the console type. Window sill models of smaller capacity are also available. Such units may be used singly, for example, to provide comfortable conditions in sleeping rooms, or in multiple to cool an entire

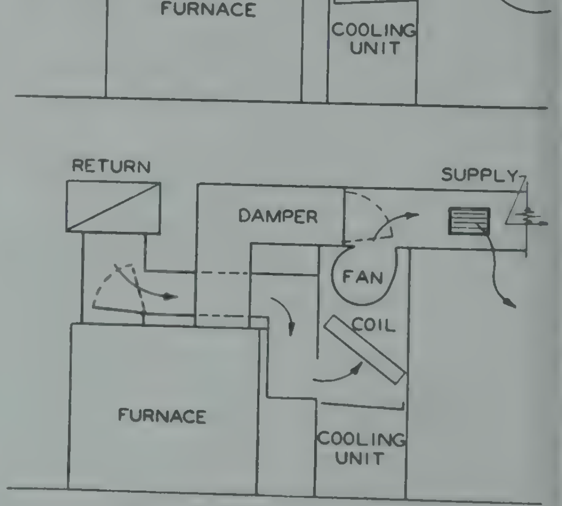
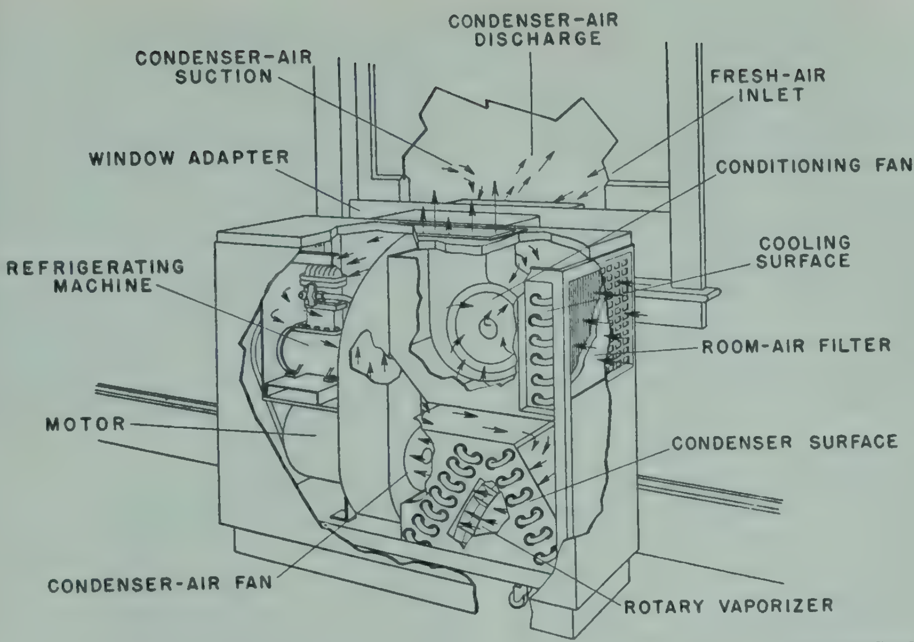


Fig. 2. Store Coolers Applied to Residences.

* Since this chapter was prepared, a few manufacturers have begun production of residential all-year air conditioners combining gas fired heating and electric refrigeration elements.



ASHVE Guide

Fig. 3. Self-Contained Air-Cooled Unit Air Conditioner.

esidence. They have the advantage of being independent of the type of heating system used and furthermore, since they employ air condensers, do not require any water for their operation. In most cases a single central unit of larger size will prove more economical than the use of multiple room air conditioners when a residence is to be completely air conditioned.

Heat Pumps

Within the last two or three years a few hundred installations have been made of heat pump units specially designed for residential applications. **Fig. 4** is an illustration of what is probably the most successful of such units. Heat pump units are capable of heating and cooling a residence without the use of any combustible fuel. Electricity is normally used as the only energy source and cooling is accomplished in the conventional manner except that the heat dissipated by the condenser is released into the earth through the well. On the heating cycle, heat is extracted either directly from well water or from a secondary fluid which is circulated through a closed loop inserted in the well. The heat absorbed at the lower temperature plus the heat equivalent of the electrical energy used to drive the equipment is released largely by the refrigerant condenser which is located in the recirculated air stream. Such installations have apparently proved successful when sufficient well water is available or when a "well loop" is used, if sufficient lateral flow of water exists through the strata which the well penetrates. At present the first cost of heat pump units including well is somewhat greater than the combination of conventional fuel fired heating equipment and conventional cooling units. Year 'round operating costs of such units are usually quite competitive with conventional heating and cooling equipment and in some areas where electric power is inexpensive, the annual operating cost for heating and cooling of a successful heat pump installation may be less than that of fuel fired equipment.

Other methods of extracting heat from the earth for use with heat pump equipment, such as burying coils of pipe several feet below the surface of the ground, have been tried with only limited success. At present no practical universal heat source has been found for use with heat pump equipment. Consequently any wide-spread application of the heat pump to residential

heating and cooling must await development of a reliable, more nearly universal heat source.

Inside Temperature and Humidity Conditions

The field of residential summer air conditioning is so undeveloped that "established practice" with respect to conditions of temperature and humidity do not exist. It can be said with reasonable certainty, however, that dry bulb temperatures exceeding 80 to 82 F during periods of extreme heat will not be acceptable to the owner, unless he has been persuaded to accept some compromise between continuous comfort conditions and cost of equipment. On the other hand, it is apparent that owners of residences equipped with summer air conditioning enjoy lower dry bulb temperatures around 73 to 75 F during more moderate outside conditions. There is some evidence that some home owners sometimes enjoy allowing the temperature to drop to 70° or below during the sleeping hours.

Ordinarily it will prove uneconomical to design residential summer air conditioning installations to maintain comfort conditions in kitchens during periods of heavy cooking loads or in living areas during periods of unusually heavy people and lighting loads such as occur during parties. These statements do not apply, of course, for deluxe installations where the owner is willing to pay substantially more money to handle these extraordinary loads.

In most residential summer air conditioning installations no attempt is made to control humidity to a fixed value. With equipment which is not liberally sized and with the limited air quantities which usually result from the use of ducts designed primarily for heating, relatively low humidity conditions result. Furthermore, most installations do not take outside air for ventilation and, with the exception of cooking, and showering, the generation of moisture within residences is quite small. Consequently, the sensible heat factor for residential cooling loads normally falls between 0.9 and 1 so that apparatus dew points even as high as 50 F will result in relative humidities under 40%, which are quite acceptable.

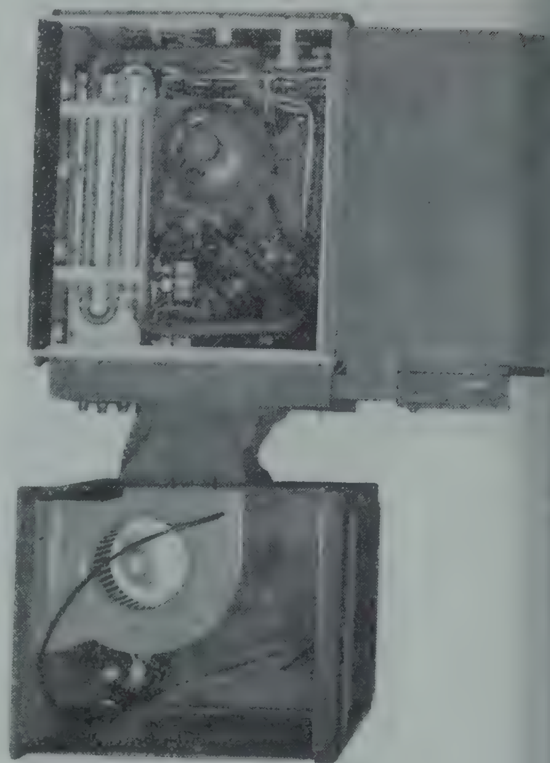


Fig. 4. Marvair Water to Air Heat Pump Unit. Parts: Electric motor and compressor on vibration isolated base. Liquid-suction exchanger—on front of base. Summer-winter switching valves—upper left of compressor compartment. Refrigerant to air exchanger—not shown (in top of compressor compartment). Water to refrigerant exchanger—not shown (under base). Circulating fan—in casing on right.

As will become apparent from the discussion of equipment selection which immediately follows, if equipment with too great a cooling capacity is applied to a residence, the refrigeration equipment will be off for too large a percentage of the time and moisture which has been removed by the cooling coil will have time to re-evaporate into the house causing unacceptably high humidity conditions.

Estimating the Cooling Load

Because of the limited nature of the residential cooling market, it is not strange that satisfactory methods for selecting residential cooling equipment have not been developed.

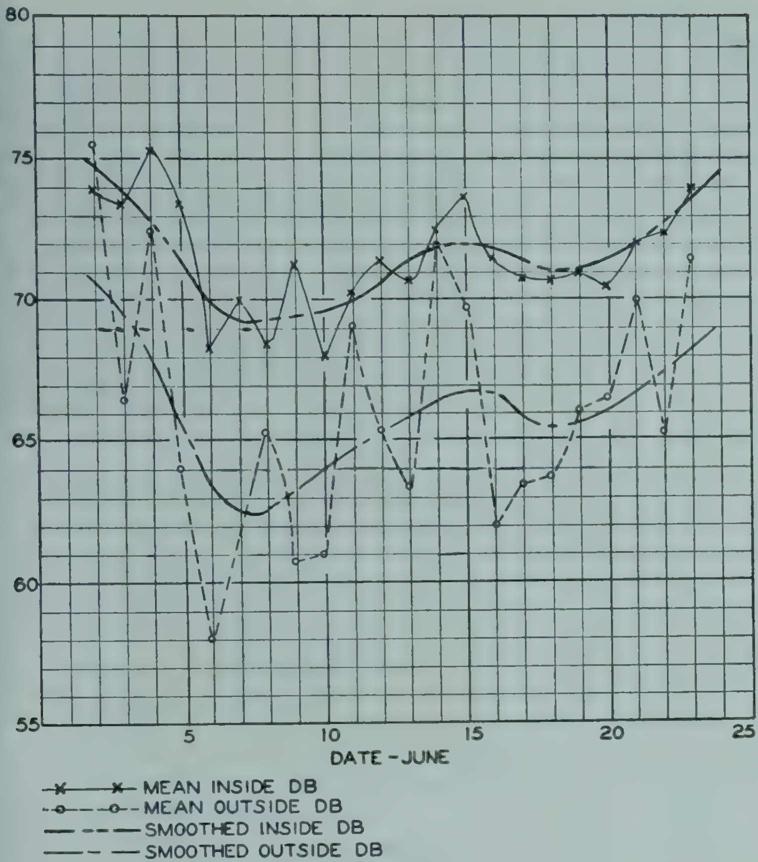


Fig. 5. Residential Temperature Record.

In commercial air conditioning the reatest percentage of the load is generally rom constant internal heat sources such as ghts and occupants. Variable heat gains rom transmission through the structure nd sunlight gains are of secondary magitude, and are usually accepted at maxiaum value. In residential air conditioning, owever, constant internal loads are small nd variable heat from external sources is he major load component. Thus an instalation sized upon the basis of maximum nstantaneous heat gain will be far overized for average load conditions. This facor is accentuated by 24-hr occupancy and peration, for at night transmission and adiation gains may be non-existent or egative.

Furthermore, in residential air condiioning the average cooling load bears a mall and favorable relation to the thermal nertia of the structure. The thermal "fly vheel" effect of the structure acts effectively to level heat gains from external sources.

These factors have not been generally recognized in past installations, with the result that most have been oversized for the actual average requirement. The most apparent result of oversizing is high first cost, but a more important factor has been unsatisfactory air conditions resulting from long off cycles. Maintenance of comfort is dependent upon reduction of humidity as well as temperature. In most installations involving the use of refrigeration, humidity reduction is obtained as a by-product of cooling as a result of condensation of moisture from the air as it passes over the cooling coils. When refrigeration stops, dehumidification stops. The thermal "fly wheel" effect of the structure serves to maintain temperatures at low enough levels to prevent the thermostat from starting the compressor for extended periods. There is nothing in the structure, however, that has any significant capacity for moisture absorption, so that humidity is likely to rise quickly to unsatisfactory levels due to re-evaporation from the cooling coil and vapor diffusion from out of doors. This is the effect referred to briefly above. Smaller equipment will tend to operate nearly continuously during warm and humid periods, thus maintaining constant and satisfactory dehumidification. Such equipment is not apt to overcool even during extended periods of cool but uncomfortably humid weather.

Much remains to be learned about the thermal storage characteristics of residential structures. However, recent experimental work conducted by one manufac-

turer reveals that residences which have roof insulation and normal frame or masonry veneer wall construction and which are kept closed while being occupied normally exhibit variations of inside temperature which almost never exceed 7 F and usually are around 5 F even though the outside temperature variation is as high as 20 to 25 F. These temperature variations were obtained even on sunny June days when the houses were subjected to maximum sun effect. These experiments also indicated that the maximum inside temperature normally occurs between 8 and 10 p.m. while the minimum occurs between 6 and 8 a.m. Incidentally all the houses tested had basements. **Fig. 5** shows a plot of the daily mean indoor temperature and daily mean outdoor temperature of one of the residences tested. This house was a typical 6-room, 2-story colonial design of frame construction with wood sheathing, clapboard siding and insulation over the second floor ceiling. It will be noted that the daily mean inside temperature stays 5 or 6° above the daily mean outside temperature. Furthermore, the inside temperture does not respond greatly to an isolated warm or cool day.

The type of thermal response illustrated in Fig. 5 is indicative of a large ratio between thermal capacity and daily or hourly heat exchange with the outside. Furthermore if an uncooled, unventilated, normally occupied residence will only vary 5 to 7° in spite of maximum sun effects and maximum outside temperature variations, then a residence which is refrigerated at a constant rate equal to the net 24 hour heat gain should exhibit the same variation in inside temperature.

Calculation of the 24 hour heat gain is similar to calculation of the instantaneous heat gain. The mean daily sol-air temperature is used for walls and roof and integrated values of sun radiation through windows may be obtained by integrating the familiar hourly tables. Because the absorptivity of clear glass is very small, its transmission is computed using the daily mean outside dry bulb (essentially the same as mean sol-air temperature for north wall) regardless of exposure or degree of shading. Of course the design *daily mean* inside dry bulb temperature must be used in all transmission calculations. Finally estimates of the 24-hour heat loads due to people, lights and other internal effects must be made.

Presumably a residential cooling system designed as suggested above for a mean temperature of 76 F would reach about 79.5 F at 8 to 10 p.m. and cool to 72.5 F by 7 a.m. on the design maximum day.

Although experience with 24-hour estimating methods for residences is extremely limited, it appears that the size of equipment which results is usually between 55 and 60% of the size which would be indicated by the maximum instantaneous heat load calculations. Until more experience is obtained, it is suggested that equipment be selected on the basis of the 24-hour heat estimate but that 10 to 15% extra capacity be provided.

Equipment Location

Central residential summer air conditioning units may be installed in basements, garages, storage room, utility rooms, or attics. Since the majority of installations will be made in conjunction with forced warm air heating systems and since water supply, electric supply and drain services are more accessible in basement or utility room locations, the equipment will be usually located immediately adjacent to the central heating unit. Since the ambient noise level in residences is unusually low, particularly at night, cooling units should not be located adjacent to, or immediately under or over the sleeping rooms if some alternative location is available. Furthermore, residential cooling equipment should have a generated noise level no higher than 55 db as measured at any point 6 inches from the equipment casing with 40 db weighting net-work.

Air Distribution

In most cases it will be found that the air distribution system designed for heating will be adequate for cooling also. A minimum air quantity of approximately 420 cfm per ton of installed refrigeration should be provided by the cooling equipment. In some cases where the fan of the heating unit is used to circulate the air

ring the cooling season, it may be found cessary to provide a slightly higher fan eed in order to overcome the additional sistance of the cooling coil. In extreme uthern locations where small heating inallations are made, it may be found necsary to size the duct work for cooling opations or provide additional ducts and n capacity which may be used during the oling season.

With modern residential construction, generally where steps have been taken reduce infiltration and where roof inlation and some double glass is provided reduce transmission heat losses, the cation of warm air outlets for heating oes not appear to be critical. Therefore, new homes where summer cooling is ontemplated, high inside wall outlet locaions are best. When cooling is applied to xisting warm air heating installations which have low wall outlets, the owner nust expect cool drafts at locations imnediately in front of outlets. However, outlets are available with adjustable vanes for directing the stream of air upward which will normally produce satisfactory conditions. Warm air outlets located in the floor in older residences perform quite satisfactorily during the cooling season.

The problem of duct sweating has already been mentioned. If the main supply ducts are in the basement, the best method is probably to supply the basement with air, either by bringing the return air through the basement or supplying the basement with a small quantity of dehumidified air. Ducts which pass through outside spaces, such as garages, or through attics should be sufficiently insulated to prevent sweating and excessive heat losses.

The direct impingement of supply air from outlets onto draperies, furniture or other organic materials which are subject to mildew, should be avoided. Also any dampness in supply duct insulation should be eliminated immediately or the insulation may be completely destroyed by mildew.

Heat Disposal

One of the most serious problems in connection with residential summer cooling or air conditioning is the supply and disposal of condenser water. In some municipalities it has been necessary to prohibit the use of water entirely or periodically for air conditioning equipment because of inadequate water supply systems. In such instances some type of water saving device is required. Either evaporative condensers or cooling towers can be used. Usually these devices are located in the yard but sometimes location in the garage or basement is feasible. Forced or induced draft cooling towers and evaporative condensers may be a source of objectionable noise and are unsightly. To avoid noise they must be generously sized and the fans run at slow speed. To hide them from the eye, shrubs or trelises may be used.

Occasionally in the case of residences surrounded by adequate ground, the owner may wish to install a small pond or fountain which can be used to dissipate the heat from the refrigeration equipment. One disadvantage of an installation using a fountain or small pond is that difficulties may sometimes be experienced in starting the equipment in hot summer weather after a long shut-down because the water in the pond gets very warm when it is not circulating. In such an event, the circulating water pump should be started before the equipment is started so that the fountain will have an opportunity to cool the water in the system.

For systems using city water it is sometimes advantageous to arrange the waste water piping so that the water may be used for lawn sprinkling after it has passed through the equipment. Where the discharge of too much water to the sanitary sewer is objectionable, another means of disposing of the condenser water is to construct a dry well of adequate capacity.

Sources of Energy

Supply of 60-cycle alternating current is virtually standard in all residential sections of the United States and it is almost always easily available at approximately 120 or 240 volts single-phase. Many residences may not have the third entrance wire installed, making 240-volt service available in the premises, but three-wire service is generally close at hand and can

be obtained at nominal or no cost, depending upon local regulations. Most electric companies are satisfied to have motors up to ½ hp operated on 120 volts, though if several are employed in a single operation, particularly if interlocked, they will recommend the use of 240-volt service, as this tends to mitigate interference with lighting and other uses and reduces wiring costs. Many companies require that motors of ¾ hp or over be operated on 240-volt service, and this requirement is consistent with most wiring recommendations. It is not safe either from the standpoint of equipment operation or electrical safety to plug a ¾ hp unit into the average convenience outlet. Most companies are satisfied to handle 3 hp and 5 hp units on single-phase, 240-volt service, though limitations upon allowable starting currents may call for special motor starting control. When loads of this nature are being considered, the local power company should be consulted. Some may be able to make 240-volt, 3-phase service available at nominal or no cost in heavy residential sections with advantage to the user in both first and operating cost. In general, however, the electric company will prefer to have the size of an installation kept to the minimum consistent with good performance and customer satisfaction. Experience with past residential summer air conditioning installations has indicated that, due to oversizing, they afforded a poor load factor and uneconomical utilization of the supply facilities. This has led some companies to view this new load askance, though there seems to be no basic reason why this feeling should continue if consumption is brought into proper relation with demand and supply responsibilities.

No problem is faced in the case of those installations using gas as the prime energy source. It is unlikely that any gas installation would be contemplated except in residences using gas as a heating fuel, in which case the existing supply should be more than adequate to handle the summer requirement.

In the case of any gas or electric installation, however, the utility involved should be consulted to assure adequacy of meter and service to handle the requirement. This precaution may avoid serious embarrassment for both the installer and the user.

Special Humidity Problems in Residences

There are two types of conditions prevalent in residences under which high humidity can produce serious damage. First is the existence of high humidity conditions in the winter which are becoming more prevalent because of increasing use of weather stripping, storm sash and insulation. The newer houses are generally more tightly constructed, more compact and the addition of weather stripping and storm sash reduces infiltration to the point where high humidity can occur in winter. If the house is properly constructed with the vapor barrier installed as near as possible to the inside surface of the wall, any damage which occurs will probably be limited to damage to paint due to condensation on window glass or perhaps condensation on

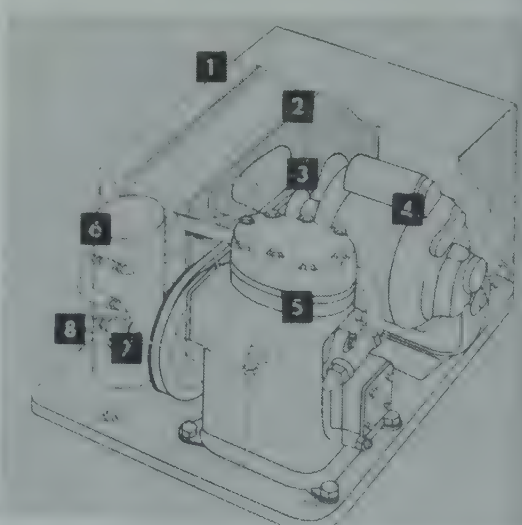


Fig. 6. Carrier Mechanical Drier.

Parts: 1. Evaporator for moisture removal. 2. Condenser transfers heat from refrigerant to room. 3. Fan of pressed steel mounted on motor shaft for drawing air over entire coil transfer surfaces. 4. Motor ⅓ hp, 115/230 volt AC with thermal overload device. 5. Compressor air cooled, 2 cylinder, circulates Freon-12 refrigerant in the system. 6. Receiver. 7. Expansion valve regulates the flow of refrigerant automatically as it flows to the cooling coil. 8. Drain pan collects moisture as it is removed from evaporator coil for disposal to open floor drain.

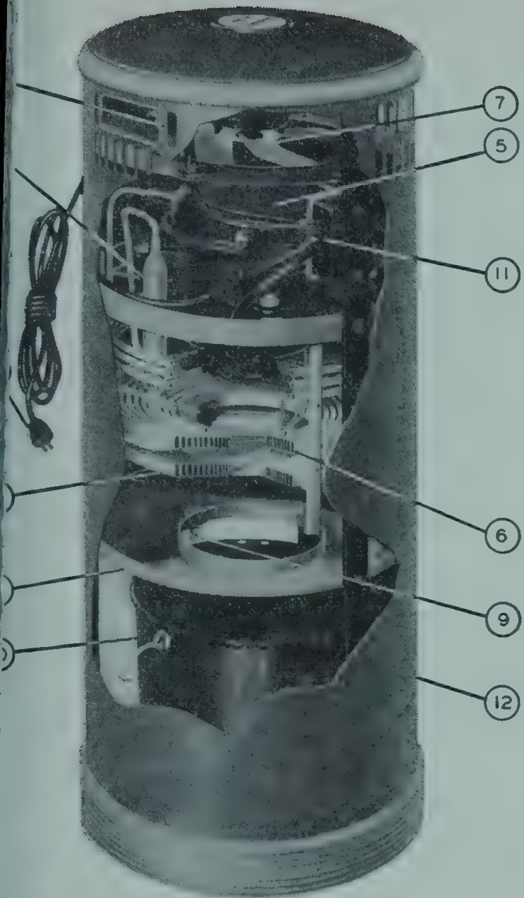


Fig. 7. Frigidaire Dehumidifier.

Parts: 1. Cord and plug. 2. Manual on-off ritch. 3. Liquid Freon-12 refrigerant control. 4. vaporator coil—condenses moisture from room r. 5. Sealed compressor with $\frac{1}{8}$ hp 115 or 230 volt C motor. 6. Condenser coil. 7. Fan to draw air ver evaporator and condenser coils and discharge room. 8. Drip pan—collects condensed moisture om evaporator coils. 9. Drip pan drain to exterior ain or bucket below. 10. Bucket—optional to exrior drain connection. 11. Compressor motor ntrol relays. 12. Decorative metal enclosure.

terior wall surfaces to the point where allpaper will become loose or come off ntirely. If the vapor barrier is not intalled near the interior surface of the wall ut instead is located near the outside surice of the wall (a practice which is still dhered to by many builders) condensaion and even ice formation can occur inide the walls which will result in serious peeling of the outside paint and eventual rotting of the wall structure itself.

To relieve high winter humidity conditions, the generation of water vapor within the house must be reduced if possible, or else sufficient ventilation must be provided to bring the humidity to acceptable values. It is quite possible that some form of high efficiency heat exchanger will eventually be devised so that air may be brought in from the outside and heated by the heat recovered by an equivalent amount of exhaust air.

High humidity conditions can also prevail in summer in residential storage spaces, particularly basements. These conditions result in mildew damage to clothing, books, and other valuable organic materials. High summer humidities can also cause rusting of tools in home workshops, photographic equipment, etc. Recently two types of apparatus have been placed on the market to relieve these high summertime humidity conditions. One is an absorptive drier usually containing either Silica Gel or activated alumina. These driers are placed in the affected spaces where they absorb moisture and reduce the humidity. After some length of time, depending on the size of the space and the size of the drier, the package of desiccant must be re-activated by heating.

A second form of unit which may be used for controlling the humidity in summer in storage spaces, etc., is shown in **Figs. 6** and **7.** These units are small portable or stationary refrigeration units, $\frac{1}{8}$ hp or larger including evaporator, compressor and condenser. The fan of the unit causes the air to circulate first over the evaporator coil and then over the condenser coil. Moisture is condensed by the evaporator coil and is drained away. There is no net refrigeration produced by these units, in fact they produce a slight heating effect approximately equivalent to the input to the motor. They will, however, maintain safe humidity conditions in fairly large closed spaces. The small unit Fig. 7 is portable, may be plugged into any A.C. outlet, and is priced for mass market sales.

If you searched this chapter for something which was not found in it, please let the editors know.

68. PASSENGER CARS

LTHOUGH it is only about seventeen years since the first general application air conditioning was made to railroad ssenger cars, it is now considered a cessary part of the equipment of all such rs irrespective of the service in which ey will be used.

Railroad car air conditioning presents culiar problems, particularly those of obining the power necessary to operate the oling unit, and of arranging a satisfacry distribution of the conditioned air in e car. These, together with the space nitations and limited opportunities for rvice, create difficult problems in degn. The satisfactory operation of the variius types of equipment on more than 5,000 cars in U.S. and Canada is evidence hat the problems have not been insurnountable.

The general **arrangement** of **equipment** s much the same on all cars. The conditioned air is supplied to the car through the ir conditioning unit, which consists of the ssembly of motor-driven blowers, cooling coil, heating coil, and plenum chamber, located above the ceiling of the car. The air is distributed to the car by means of ducts between the ceiling and the roof. Proper distribution throughout the car is obtained by adjustable duct outlets or by perforated ceilings.

The total **amount of air circulated** is from 2000 to 2400 cfm; 30 to 50 percent in the latest type of equipment is outside air, and the remainder is recirculated. Some installations have adjustable air intakes so that the air circulated under suitable weather conditions may be all outside air.

Some sleeping cars are so equipped that the air circulated is 100 percent outside air so long as the refrigeration capacity required is below the maximum capacity of the equipment. When that capacity is reached the outside air quantity is automatically reduced to 40 percent of the total circulated.

The cooling capacity required is from 8 to 10 tons, depending on the car construction and number of passengers carried. Construction being equal, the largest capacity will be required by coaches and dome cars.

Filters are provided for both the outside and recirculated air. As the outside air contains particles varying in size from large cinders to fly ash, the design of a satisfactory filter is a problem. Present practice is the use of filters 4 in. thick for outside air and 2 in. thick for recirculated air.

Activated carbon filters are being used to some extent to adsorb odors from the recirculated air, lessening the amount of outside air required.

Electric precipitation has been applied to a limited extent to remove the finer particles, the coarser material being taken out by mechanical separation.

The refrigerating apparatus is located outside the passenger space—in most instances, under the car body.

The **cooling system** used will be in one of the following classes: Ice bunker, mechanical compression, or steam ejector.

Ice Bunker System

Melting ice furnishes the source of cooling with this system. The ice is placed in insulated bunkers under the car body. The cooling coil in the air conditioning unit is suited to heat transfer between circulating water and the air to be cooled.

A motor-driven pump circulates water from a sump beneath the bunker to the

GEORGE E. HULSE, Author, Chapter 68. Born 1/21/77 in Bellport, N.Y. Educated at Stevens Inst. of Technology, ME, 1902. Formerly, Assistant Engineer, Safety Car Heating and Lighting Co.; Engineer of Tests, 1903; Chief Engineer, 1907 to retirement, 1946. In charge of design and quality control of equipment for lighting railway cars by gas and electricity, heating by steam and air conditioning. Developed a mechanical system for cooling refrigerator cars.

Author, Chapter 63, 1946 Applications Volume, ASRE Data Books.

Fellow, Amer. Soc. of Refrig. Engrs., President, 1940; Fellow, ASME; member, AIEE.

cooling coil, and from there to the ice bunker where the circulating water comes in contact with the ice, and is cooled before passing to the sump for further circulation.

Control of car temperature in the simplest form is by a thermostat operating from dry bulb car temperature, which starts or stops the water circulating pump, and thereby the supply of cooled water to the air conditioning unit, or the thermostat may operate a valve in the water circulating system which will bypass the circulating water around the ice bunker when the car is cooled to the proper temperature.

A further refinement is to have the bypass valve opening controlled by a thermostat in the outside air so that the proportion of cooled and recirculated water can be proportioned to the cooling demands as determined by the outside temperature.

As the cost of ice is a large item of expense in the operation of this system, it is desirable to discharge the water from the melted ice at as high a temperature as possible. This is accomplished by discharging it through auxiliary coils so placed that the outside air passes through them on its way to the air conditioning unit. The higher temperature of the outside air permits this water to be discharged at a temperature considerably higher than if it were discharged directly from the main cooling coil.

Steam Ejector System

The steam ejector (Fig. 1) takes stea from the locomotive through the train li already provided for heating the car passes it through an ejector which is co nected to a flash tank or evaporato evaporating a part of the water at lo pressure and temperature, and cooling th remaining water in the evaporator. Th steam and vapor are compressed in th ejector to a pressure at which they can b condensed by the surface condenser t which they pass from the ejector. The con denser is cooled by the combined actic of a water spray and an air blast (evapora tive condenser). The condenser tempera ture, therefore, is a function of the atmos pheric wet bulb temperature.

Air is purged from the condenser by a water ejector operated by the condense spray water which is pumped through th purge ejector before going to the sprays Enough of the condensed steam and vapo from the condenser is automatically re turned to the evaporator to make up the amount evaporated in the evaporator; the remainder is used in the condenser cooling system.

A circulating pump takes the cooled water from the evaporator and circulates it through the cooling coil of the air conditioning unit.

The refrigerating unit of the steam ejector system, which contains the condenser, fans, fan motor, condenser water spray,

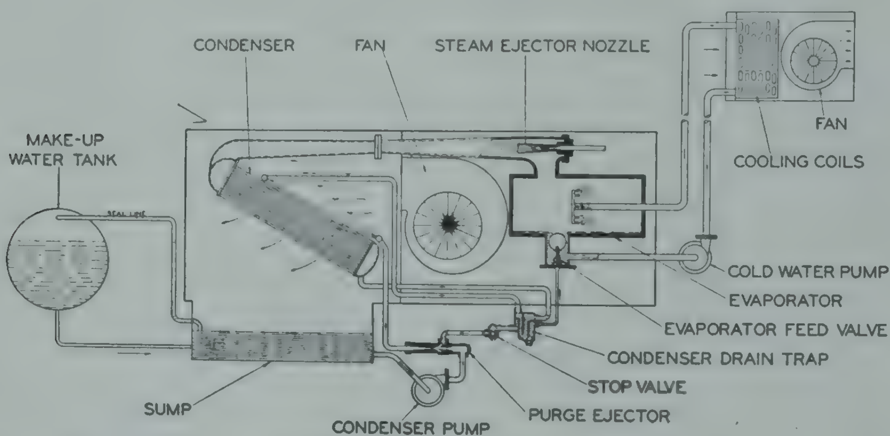


Fig. 1. Steam Jet System. Diagram of Operation with Underframe Refrigerating and Roof Mounted Air Conditioning Unit.

porator and steam ejector, is made in e types, one designed for installation veen the car ceiling and roof, one for inting beneath the car, and one for in-ation in a compartment in the car it- The choice as to the particular type ends very largely on construction fea-s of the particular car to which equip-it is to be applied. Generally speaking, roof-mounted is preferable from the ndpoint of maintaining clean condenser faces, as the air which is taken in at the of the car is cleaner than that near the dbed. It has the disadvantage of adding ne weight at a relatively high point, and uires a roof hatch in order to make the uipment accessible for maintenance.

Where a compartment can be provided the car itself, that arrangement is pref-able as it has the advantage of the roof ounted type without the disadvantage as weight placement.

On the newer cars there is generally in-fficient room between the ceiling and roof r the installation of the refrigerating unit one of the other types is used in these rs.

The car temperature is generally con-olled by a dry bulb thermostat placed in e path of the recirculated air near the in-t to the air conditioning unit. This ther-ostat controls the motors of the con-enser fan, steam inlet valve, and con-enser spray pump to start and stop the peration of the cooling unit in accordance ith the car temperatures.

In the early installations the tempera-ure to be maintained was selected by the car attendant, but later installations have the temperature selected by a thermostat in the outside air, this temperature setting being modified or adjusted by a wet bulb thermostat in the car.

When the off cycle is long, due to light refrigeration load, undesirable conditions may exist during the off cycle due to evaporation of water from the cooling coil and loss of dehumidification of outside air as a result of rise in temperature of the coil.

A number of cars with the steam ejector equipment have a thermostat in the cold water circulation, which when the car thermostat has stopped the operation of the cooling equipment will restore its oper-ation when the cold water temperature rises to 68 F, irrespective of the car tem-perature. If the water is not allowed to go above 68 F there will be no evaporation from the cooling coil to cause high humid-ity in the air.

Mechanical Compression System

The mechanical compression systems are all alike in that a compressor **(Fig. 2)**, generally of the reciprocating type, is used to supply compressed refrigerant to an air cooled or evaporative type **(Fig. 3)** con-denser, where it is liquefied.

In some instances the condenser is cooled only by air, but in order to provide sufficient condenser capacity where high dry bulb temperatures are encountered, a water spray may be added, which is put into operation only when the condenser pressure reaches a high point.

The reduction in the amount of power

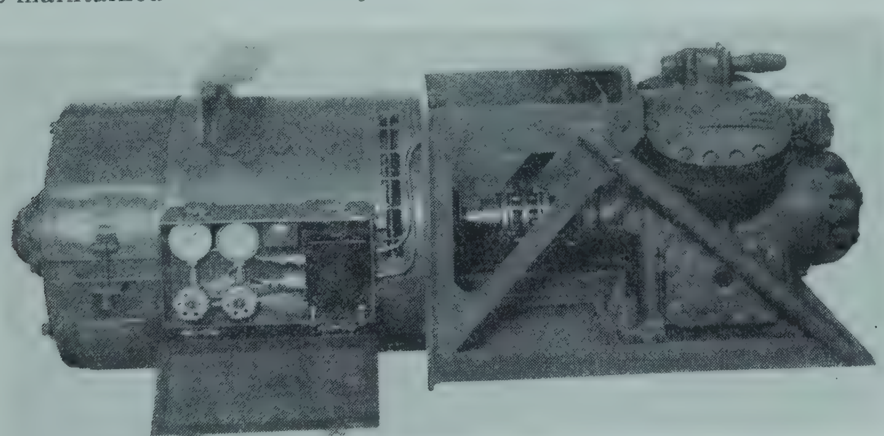


Fig. 2. Direct Connected Motor and Freon Compressor Assembly.

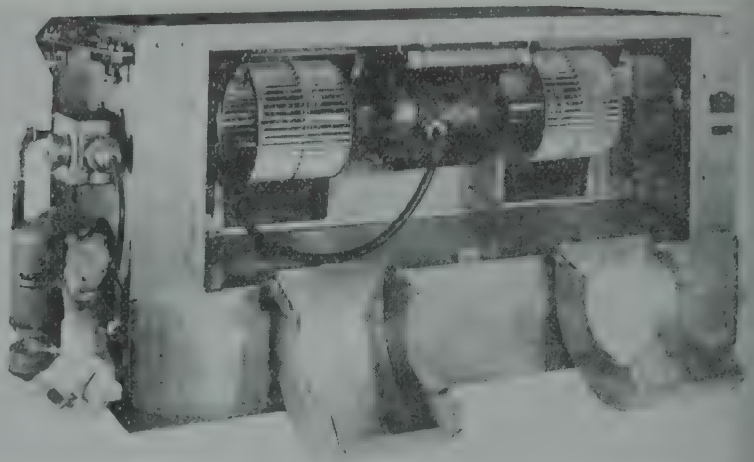


Fig. 3. Railway Evaporative Condenser Unit.

required secured by the use of the evaporative condensor with water sprayed on the tubes under all conditions of operation has led to the use of that type as the latest preferred practice.

The liquid refrigerant is passed to a cooling coil through an expansion valve, absorbing heat and returning to the condensing unit. Freon is used as the refrigerant in all systems. The fan in the air conditioning unit is driven by a motor receiving its current from the electrical system of the car.

Based on the kind of compressor drive, this class of system may have the compressor driven in the following ways:

1. Direct from the car axle
2. By an electric motor
3. By an internal combustion engine.

1. Direct drive. The compressor and condenser fan are driven from the car axle by means of V-belts and a bevel gear arrangement which rotates a compressor drive shaft having its axis parallel to the longitudinal centre line of the car. As the car operates with a wide range of speed it is necessary to place a speed control between the drive shaft and the compressor to limit the maximum compressor speed. This speed control is a speed governed induction clutch. The compressor and condenser fan are so designed that they will operate properly when their direction of rotation is reversed by change in direction of the car movement.

With this type of drive no cooling is obtained when the car is stationary and the amount is reduced when the car runs below 20 miles per hour.

An auxiliary motor can be connected to the driven member of the speed control to operate the compressor and condenser when the car is stationary for a considerable period, but this is not usable for the usual station stops.

Control of this system is by dry bulb thermostat which operates to excite the clutch and drive the compressor when cooling is needed.

2. Electric motor drive. The compressor is driven by an electric motor either by means of V-belts, or direct connection. The motor may be for direct current receiving its power from a generator driven by the car axle when the car is in motion, or from a storage battery when the car is standing. The condenser fan may be driven by this motor, or by a separate motor.

There is a further division in this type of installation, because of the difference in the way the compressor is operated during times when cooling is required and the car is standing for such long periods as to make it impractical to operate from the car battery. In one instance, the compressor motor is designed so that it can be operated either from D-C or A-C. The current generally available from stationary lines is A-C. Connecting the compressor motor to such a line provides cooling when the car

stationary. The D-C motor may be de-ned to operate as a generator when it is ng driven by the A-C motor, and thus nish some battery charging.

With the other arrangement the axle-iven generator has an A-C motor ounted directly on its armature shaft. hen the car is standing the generator is tomatically disconnected from the axle d may be driven by the A-C motor, oper-ing with the same voltage, current and ttery charging control as it does when it being driven from the axle.

A number of cars have recently been uipped with a system in which the com-essor is driven by an A-C motor. Power is tained from an A-C generator driven by a iesel engine which operates continuously hile the car is in service. The engine ives two generators in one frame, one pplying power at 220 volts for operating e compressor motor, and the other at 120 olts for lighting and other requirements.

Original installations of compressor sys-ems had the car temperature controlled y stopping and starting the compressor nd condenser fan by a dry bulb thermo-tat, the temperature being selected by the ar attendant. A later modification was utomatic setting of the temperature to be aintained by a thermostat in the outside ir modified by a wet bulb thermostat in he car.

In practically all new equipment modu-ated cooling is used to overcome high umidity conditions during the off cycle. This condition occurs when the equipment s operating under light load and the off ime is extended. The cooling coil is di-ided into two equal sections one half hav-ng a valve in the liquid line, which stops he supply of liquid refrigerant to this part f the cooling coil through the action of he car thermostat when the car tempera-ure approaches the desired value. The ther portion of the cooling coil is kept in peration, and, if it has sufficient capacity o reduce the car temperature further, the emperature is controlled by cycling the ompressor on and off.

The reduction in compressor capacity to neet the reduced demand when half the oil is used is accomplished either by reducing the compressor motor speed or by the operation of a compressor unloading device through the reduction in the compressor suction pressure.

The compressor with its driving motor, the condenser and its fan were formerly, and are still to some extent assembled in a single unit mounted beneath the car. Present practice favors a separate assembly for the compressor and its motor (Fig. 2). A dry condensor unit or an evaporative condensor unit (Fig. 3) is used with such a compressor assembly.

3. Internal combustion engine drive. With this system a reciprocating or rotary compressor is driven from the engine, either by direct connection or through a V-belt drive.

The condenser may be air-cooled by a fan driven from the engine shaft, or by a fan with electric-motor drive. Evaporative condensers are also used having electric-motor drive. The condensing unit is embodied in one assembly, current for the air conditioning unit fan motor and the condenser fan motor, if used, being obtained from the car electric system. Control of the car temperature is by means of control of the engine speed through the suction pressure of the compressor.

The air conditioning unit may be of the single coil or divided coil type.

The fuel used is liquid propane, carried in cylinders underneath the car. Automatic valves are provided to prevent the escape of the fuel in case of breakage of piping.

Diesel type engines are also used for this type of equipment.

Comparison of Systems

The choice of the type of equipment to be used depends upon the conditions under which it is to be used.

The water ice system involves a low application cost, but the cost of operation is high, so that it is used only where ice is low in price, labor cost to load the ice bunkers is low, and the cooling season short, for example in Canada prior to the war.

The first cost of each of the other systems is approximately equal and the operating and maintenance costs are comparable.[1]

The compression system with electric drive has the advantage of flexibility of control, and low maintenance cost. It requires power from the locomotive, which may reduce the number of cars which can be handled.

The same can be said of the compression system with direct drive except that the power required is somewhat greater due to the slip of the speed control at high train speeds.

Both systems using internal combustion engines mounted on the car, either driving the compressor through an electric motor, or by direct connection have flexibility of control and require no power from the locomotive. Offsetting this is the necessity of providing a fuel supply, and the main tenance of the internal combustion engine

The steam ejector system uses little o the power of the locomotive but requires a steam supply. The amount used is the sam as that required for heating in the winte so that locomotives are designed with tha amount of steam available even though the motive power may be Diesel engines o electric motors. This system does not re quire a refrigerant other than water, whicl may be an advantage.

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69. BUSES

AIR conditioning first applied to the intercity bus in 1938, is now consid-red a necessary part of its equipment. On he other hand, the application of air con-itioning to the city bus is still in the ioneering stage, although the problem is ne more of economics than of engineering. Iowever, two important applications of air onditioning in the field of urban passen-er transportation have been made, one in San Antonio, Texas and the other in At-anta, Georgia.

When considering the application of air conditioning to buses, we must remember that buses are commonly divided into two general classifications; intercity and city. Although these two types of buses, serving different fields of passenger transportation, use the same basic air conditioning equipment, nevertheless, the problems involved are different.

Intercity Bus

The intercity bus serves the field of long distance over the highway passenger transportation. The growth of air conditioning of this type of vehicle was rapid following its introduction in 1938, until today air conditioning is standard equipment.

Because the dimensions of buses are limited by law, the cooling load does not vary greatly between different intercity bus designs, if we except recent radical innovations with observation roofs which are in the experimental and developmental stage. The capacity of the average cooling system is in the neighborhood of four tons, which is sufficient to maintain, with a full seated load, an inside condition of 78 F dry-bulb, 67 F wet-bulb when the outside condition is 95 F dry-bulb, 78 F wet-bulb. In the West 110 F dry-bulb and 80 F wet-bulb will doubtless be encountered and may have to be designed for. Although extreme temperature conditions may be encountered by a bus which travels anywhere there is a highway, this capacity is adequate to maintain comfort conditions except for the infrequent extreme weather condition. Although, more capacity would be advantageous, the space and weight limitations on the equipment discourage the objective. **Fig. 1** illustrates commonly attained design conditions in the average 40 passenger intercity bus.

City Bus

The city bus serving the mass transportation of people in metropolitan areas presents a more difficult problem to the air conditioning engineer. Doors are being opened at every street corner and peak passenger loads are extremely high. **Figs. 2** and **3** illustrate actual data on this phase of city bus operation recorded in San Antonio, Texas.

On the other hand, the average ride is of short duration, seldom allowing time for the passenger to become completely acclimated to the inside conditions. Therefore large temperature differences need not be maintained and are not desirable. The present meager information available indicates that capacities of from five tons on a 35 passenger bus to six and one-half tons on a 48 to 50 passenger bus should do a fair job of cooling the city bus. This is not to say that comfort chart conditions will be maintained during rush hours when the bus is carrying up to 100 percent standees. Rather this capacity will maintain comfort conditions in all but the rush hours and conditions that are an appreciable improvement over outside conditions during periods of standee loading. **Fig. 4** il-

ANDREW T. BROWNE, Author Chapter 69. Born 1905, in Belfast, Ireland. Educated at City of Belfast College of Technology, ME, 1923. Formerly rail car designing, Pullman Car and Mfg. Corp., Chicago; bus air conditioning design, automotive research, ACF-Brill Motors Company, Philadelphia, 1929 to date.

Co-author, "Problems Involved in the Adequate Heating and Ventilating of Buses," Assn. of Transit Equip. Men, 1938. Author, "Air Conditioning is No Mystery," Bus Transportation, 1938; "Air Conditioning of Automotive Vehicles," SAE, 1950; Chapter 64, 1946 Applications Volume, ASRE Data Books.

Member, ASME, SAE, registered professional engineer, Pennsylvania.

At present, Project Engineer, ACF-Brill Motors Co., Philadelphia, Pa.

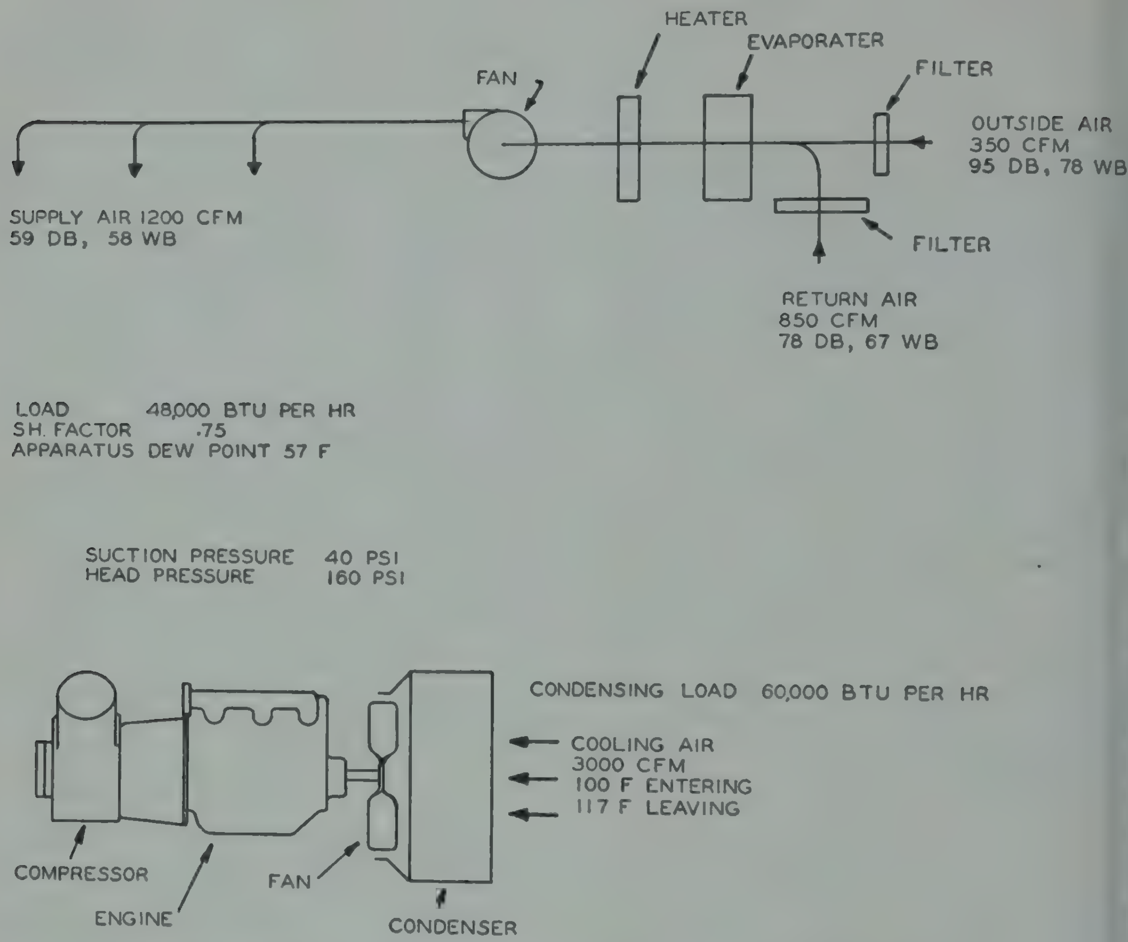

Fig. 1. Design Conditions on an Average 40 Passenger Intercity Bus.

lustrates the inside conditions at people loads in excess of seated capacity which these amounts of cooling will maintain in the average city coach.

The leading problem on the city bus however is economic and not engineering. It is not determined as yet whether air conditioning can pay for itself in increased patronage. The difficult unanswered question is whether the comfortization of buses during the summer months will attract sufficient additional riders during the off-hours to justify the additional capital expenditure and maintenance costs. Until a favorable answer is obtained to this question the application of air conditioning to urban transportation will be slow.

Body Design Considerations

The design of the air conditioning unit is not limited to the design of the cooling equipment. Instead, the air conditioning engineer must interest himself in the basic design of the vehicle. The required cooling load must be kept to an absolute minimum by improved body construction; infiltration be reduced to the least possible amount by tight body construction, special attention being required by such items as the sealing of windows and doors.

It is important that the shell be well insulated. Conventional bus construction consists of an outer metal skin fastened to a metal frame and lined on the inside with metal or composition panels. The thickness of this shell varies from 1½ to 2 inches. The space between the outer and inner panels should be filled with a blanket of insulation which is most frequently cemented to the outer panels. This insulation should be fire and vermin proof, and preferably be an inorganic material. The floor is ply-

FRONT ENTRANCE DOOR OPERATION	CENTER EXIT DOOR OPERATION
Door open—7½ times per mile	Door open—5½ times per mile
—70 times per hour	—44 times per hour
—35% of operating time	—15% of operating time
Longest time door open—55 seconds	Longest time door open—34 seconds
Shortest time door open—3 seconds	Shortest time door open—3 seconds
Average time door open—13.5 seconds	Average time door open—12.5 seconds

Fig. 2. Actual Door Operation Data Taken During the Rush Period on a 35 Passenger City Bus in San Antonio, Texas.

wood with a linoleum covering and should have a minimum equivalent of a ⅜ inch layer of cork between. The metal framing members provide paths for heat flow between the inner and outer surfaces and the continuity of these paths should be interrupted wherever possible. Unfortunately, with present types of construction this is difficult, but a minimum of a layer of cork tape between the inside panels and the frame should be used.

Because of the large area of glass in a bus, heat gain due to solar radiation is an important item in the cooling load and heat absorbing glass is valuable in reducing the solar load. Double sash is also desirable, but because of the weight and cost penalty, it has found no favor. Window shades are used on intercity vehicles and preferably the outer surface should have a high reflectivity. Some benefit in reducing the load due to solar radiation may be obtained by a judicious choice of exterior color schemes. Certainly, the roof paint should be a light colored pigment having a high reflectivity.

Fixed windows are desirable, but must be openable in the event of an air conditioning failure. To prevent passengers from opening the windows, the normal practice is to provide them with locks that can only be opened with a key.

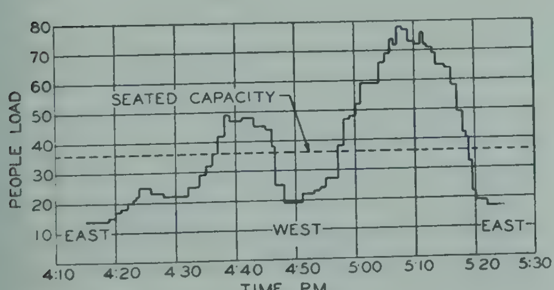

Fig. 3. Passenger Load in a 36 Passenger Urban Coach During the Evening Rush Period in a Southern City.

Equipment

When it is realized that the weight and dimensions of highway vehicles are limited by state regulations, it will be realized that the weight and physical dimensions of the air conditioning equipment must be kept to an absolute minimum. The weight of a modern 35-foot intercity coach ready for the road is in the neighborhood of 20,000 pounds, of which approximately 1,200 pounds is due to air conditioning. This is equivalent to the weight of eight passengers or about 20 percent of the total passenger load.

The mechanical compression system of refrigeration is used exclusively. Freon 12, because of its non-toxic and non-irritating properties in the event of a leak, is the commonly used refrigerant.

The absorption system has always been a subject of discussion in automotive circles because of its attractive feature in requiring only low-grade energy, a source of which is available in the rejected heat of the propulsion engine. However, the development of the system has not progressed to the point where it can be seriously considered for bus use.

High-speed reciprocating type compressors, capable of operating safely at 2,500 rpm, have replaced the old conventional cast iron machines. The aluminum alloy crankcase is a recent development which has made a substantial reduction in compressor weight. Cylinder unloaders, which allow the displacement to be varied automatically to suit the load, contribute to improved functioning of the equipment.

Condensers are of the air-cooled, dry type. Evaporative condensers using a water spray have been tried but have not

been favorably accepted due to the additional maintenance, the need to carry a tank of water, and the difficulties due to deposits on the coils when unfavorable water conditions exist. Copper coils are used although aluminum coils are being experimented with. Aluminum coils are interesting because of their weight saving, but their somewhat lower transfer efficiency results in the undesirable feature of requiring more space.

Evaporators are of the direct expansion type controlled by a thermostatic expansion valve. It is desirable that the expansion valve be of the limited gas charge type, designed to limit the maximum evaporator pressure to 55 psi. This is particularly true if the evaporator is located in the roof, because when the bus is parked in a hot sun the coils may become extremely hot, which would cause excessive suction pressure when the unit is first started unless the expansion valve limits the pressure. Aluminum evaporator coils are receiving experimental consideration but have not yet been adopted.

The disposal of the various units is dictated by the design of the bus. The high side is located under the floor in a position determined by the space available and the weight distribution on the wheels. The location of the low side is determined not only by the space available and the weight distribution, but by the problems of connecting it with ducts for the distribution of the conditioned air and the entrance of ventilation air. The low side may be located under the floor, in which case vertical ducts are required for conducting the cooled air to the overhead distribution ducts and the ventilation air to the unit. These ducts are not easy to design into the bus, although they have been incorporated in some bus designs in a very satisfactory manner. Some bus designs permit the low side to be located overhead of the driver, a location which makes for simple ducting. On other designs, the low side has been located overhead in the rear, or underneath the rear settee.

In locating the equipment, it is imperative that every consideration be given to the accessibility of the units for maintenance and also to their easy replacement. A

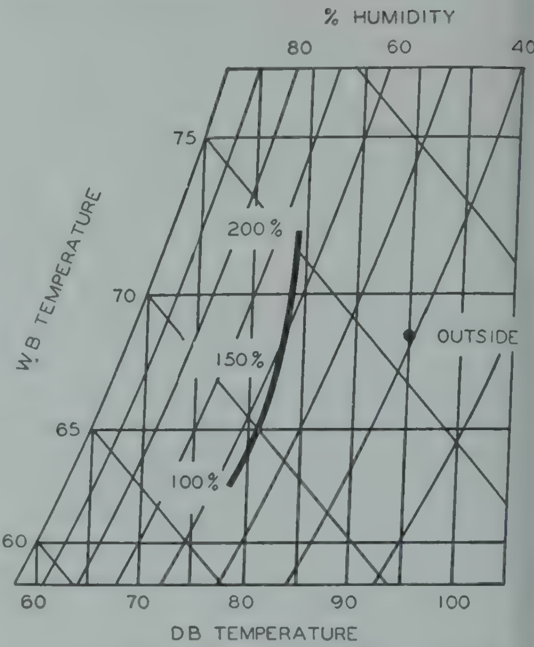

Fig. 4. Inside Conditions Presently Attained at Passenger Loads Above Seated Capacity in Urban Buses.

bus represents a large investment and only when it is on the road is it earning a return. Operating schedules allow only a minimum time for maintenance, and equipment which is not accessible will not be maintained.

There are three methods in use for driving the compressor and condenser fans:

1. Direct from the propulsion engine
2. By a separate internal combustion engine
3. By an electric motor.

In the direct drive, the compressor and condenser fans are driven by means of "V" belts from a pulley which may be mounted on the front end of the propulsion engine crankshaft. This drive has the advantage of making for a minimum of mechanical parts and therefore results in an arrangement requiring a minimum of maintenance. The disadvantage of the drive is the variable speed at which the condenser fans and compressor will operate resulting in a variable output. On intercity coaches, this is not a serious disadvantage for highway operation because a high average road and engine speed is maintained. The direct drive cannot be used for city operation because of the low average speed

this type of operation. In normal city ration, the engine is at an idle speed for least 30 percent of the operating time.

More frequently, the compressor and ndenser fans are driven by means of a arate gasoline engine. Generally, the npressor is directly connected through lexible coupling and bell housing to the r of the engine with the condenser fan unted directly on the crankshaft at the posite end of the engine. The separate gine drive is, from an air conditioning ndpoint, more satisfactory than the ect drive, in that the condensing unit ay operate at a constant speed, or at a eed best suited to the load. For the usual ur ton system, an engine of 80 to 90 cu in. splacement and developing 18 to 20 bhp 2000 rpm is required. The disadvantage the separate engine drive is the high cost volved maintaining the small four cylin-er gasoline engine. This engine is operat-g at a constant speed and constant throt-e which is a severe type of operation. For tisfactory engine performance the follow-g conditions should be observed:

1. The engine should have at least a 25 percent power margin over the maximum horsepower output demand.
2. Stellite-faced exhaust valves and inserts should be used in order to minimize the adverse effects of lead deposits and resist the tendency of exhaust valves to scale and burn.
3. Valve rotators are desirable.
4. The gasoline used should be of good quality gasoline with a minimum tetraethyl lead content. Trouble may be expected from lead salt deposits on the spark plugs if the tetraethyl lead content exceeds one cc per gallon.
5. Lead salt deposits are very brittle and their accumulation can be minimized if there are thermal changes which will cause the brittle coating to crack before excessive deposits are built up. It is desirable in the design, therefore, to have a system which will avoid constant load on the engine but instead will cycle the load in such a manner as will cause thermal shocks.
6. The engine cooling water should be maintained at 180 F.

The use of an electric motor for driving the compressor and condenser fans makes an ideal drive both from the standpoint of air conditioning and also the ease with which it may be controlled. The electric motor drive, however, is restricted to trackless trolley operation as it is not possible to use the necessary horsepower motor on a motor bus. In selecting a motor for use on a trolley bus, an investigation should be made of the low voltage conditions, as large voltage drops may exist on lines remote from sub-stations during rush hours.

Ventilation

Odors must be kept below objectionable concentrations by the introduction of sufficient outside air, or by the use of suitable air recovery equipment. The principal causes of odors are: (a) body odors from occupants, (b) exhaust fumes from the engine, (c) tobacco smoke, (d) odors from waste food particles, (e) accumulation of slime and dirt in cooling coils and ducts, (f) musty odors from upholstery.

The dilution of the inside air by the introduction of a suitable quantity of outside air is the simplest method of keeping air contamination within acceptable limits. In general, in a bus where only one or two people are smoking at a time, 10 cfm ventilation air per passenger will accomplish this purpose. This amounts to 350 cfm in an average 35 passenger intercity coach, which is approximately 30 percent of the total air circulation. In a city coach, which carries considerable standees during rush hours, the introduction of sufficient ventilation air to keep the odor concentration within acceptable limits may impose an undesirably high cooling load on the equipment. In this case, the use of air recovery equipment is indicated. Activated carbon panels located in the return air intake have been found to be the most satisfactory available method of removing odorous vapors from the inside air.

In order that exhaust fumes and other exterior odors may be excluded as far as possible, it is desirable that the quantity of ventilation air be such that a small positive pressure is maintained in the vehicle which

will assist in keeping infiltration to a minimum.

In the motor bus, the ventilation air is best taken in at a location in the forward half of the roof as it is here the cleanest air is available. Openings in the rear portion of the bus are inadvisable because of the envelope of exhaust gases which cling to the rear of a bus in motion. These limitations do not apply to the trolley bus because of the absence of exhaust on this vehicle. The design and shape of the ventilation air intake in its relation to the contours of the surrounding skin must be such that the average pressure over the intake is substantially zero at all road speeds, otherwise the quantity of ventilation air will vary with road speed. It is frequently necessary to develop, experimentally, the final contour of the air intake on the pilot coach.

For nominal quantities of ventilation, there is no need to provide exhaust openings, as even with the best construction sufficient leakage can take place.

Air Distribution

The high passenger density and the relatively low ceiling height make the problem of obtaining uniform temperatures and air motion a difficult one. Yet, proper air distribution is essential if the comfort to be gained by cooling and dehumidification is not to be completely nullified by drafts or air stagnation.

Perforated ceiling ducts for the supply of the conditioned air have proved to be a good solution to the problem. Since these ducts introduce the air at many points over the passenger space complete diffusion is accomplished very rapidly.

Return air ducts may be dispensed with provided the intake grille can be located so the entering air velocities around the grille will not prove uncomfortable to the nearest passengers.

Separate attention should be given to the problem of driver comfort. As he is working, his comfort conditions differ from that of the passenger. Additional spot cooling by means of a louvre of the Punkah type, allowing the driver to direct a mild blast of cool air over his body as he wishes, is a good solution to the problem of driver comfort. Commonly, the static pressure in
the distribution system is inadequate f
this purpose and it is necessary to augme
it with a separate small fan.

Noise

Low noise level and good vibration isol
tion are necessary. It is true that when
operation the noise and vibration from t
propulsion equipment and tires may mas
that from the air conditioning, but th
only serves to accentuate the air conditio
ing noise when the bus is stopped and t
other noises have been eliminated. A hig
external noise level from the condensi
equipment can be most objectionable t
residents along the route or in enclose
terminals.

Humidity Control

In the early days of bus air conditionin
no attempt was made to regulate humidit
beyond the proper selection of the a
paratus dew point. The only control of th
system was by a simple "on" or "off
thermostat sensitive to dry bulb temper
ture. It was soon found that this did n
maintain comfortable conditions durin
evening operations and period of low se
sible heat load, if latent cooling was r
quired. Also when the thermostat wa
satisfied, causing the system to go on th
non-cooling cycle, the re-evaporation
moisture from the wet surface of the co
resulted in the interior wet bulb temper
ture increasing more rapidly than the dr
bulb temperature. The modern bus ai
conditioning system endeavors to contr
the humidity under these conditions, eithe
by the use of reheat or by increasing th
coil by-pass factor.

Considered solely as a matter of comfor
the reheat method is the more satisfactor
method of humidity control, and the pro
pulsion engine cooling system provides
readily available source of 180 F water fo
reheat. The reheat coil follows the evapo
rator coil and the two coils may be mad
into one assembly. The flow of water to th
reheat coil is modulated, by a thermostati
cally controlled valve in the supply line, t
the correct flow necessary to maintain
minimum temperature, about 74 F, in th
coach. The disadvantage of reheat is tha
it maintains a high compressor load, which

hen separate engine driven means more onstant engine throttle with the disadvantages previously mentioned. The reheat ystem is also heavier and requires more pace than the by-pass system. Hot gas reeat has been used experimentally, but ith the availability of hot water on the iotor bus its use has no advantage. On a olley bus installation, electric current has een used for reheat.

The by-pass method of humidity control s it is used in buses is to have the thermotat take control of the expansion valve nd cause it to restrict the refrigerant flow o the evaporator below a predetermined iinimum temperature. The effect is to tarve the coil and use only a portion of it or cooling. The by-pass factor of the coil vill increase and the coil will operate at a ower-than-normal suction pressure. Conequently, the capacity of the coil will be educed and the apparatus dew point of its vorking portion lowered. Unfortunately, his method of control must do some sensible cooling at any time latent cooling is aking place and therefore, there will be onditions at which ideal comfort can not e achieved. However, from a practical tandpoint, the by-pass control does a very cceptable job.

Controls

While it is desirable that the bus air conditioning system be completely automatic to relieve the driver of any responsibility for its proper functioning, the first emphasis should be on reliability, and frequently desired refinements must be sacrificed to dependability. The most vulnerable parts of the air conditioning system are its controls and nothing can be more aggravating than the failure of a system a couple of hundred miles from a maintenance garage, which failure is found later to be due to nothing more serious than a dirty contact on an automatic switch. No matter how simple the cause of failure, if it occurs on the highway on a hot day, it is a serious matter, certainly not conducive to passenger good will. **It, therefore, behooves the designer to keep the controls as few and reliable as is consistent with satisfactory operation.**

The control of comfort conditions is most frequently accomplished simply by a thermostat sensitive to sensible temperature, which limits the minimum temperature by controlling a reheat coil or by increasing the evaporator by-pass factor and thereby regulating the humidity indirectly. Although, in practice, these controls have generally been found to be adequate, humidistats in conjunction with thermostats have been used for a closer control of marginal conditions.

A recent development is the drum switch powered by a thermal element which may be designed to set up any desired sequence of operations from cooling to heating depending upon the inside temperature.

To avoid freezing on the evaporator coil, it is necessary that a low limit be set on the suction pressure. One method in use is to stop the compressor on low suction pressure, and with a separate engine drive, this may easily be accomplished by a pressurestat in the suction line designed to open the ignition circuit when the suction pressure at the compressor falls to about 24 psi. Another method is to unload the compressor rather than stop it on low suction pressure. This is accomplished by a bypass circuit around the compressor and is controlled by a valve similar in design to a constant pressure expansion valve.

For the protection of the mechanical units, it is necessary that some means be employed to protect the system against excessive head pressure. A pressurestat controlling a solenoid valve in the liquid line is used and so designed that if the head pressure reaches 250 psi the pressurestat opens the circuit to the solenoid valve causing it to shut off the flow of refrigerant to the evaporator. When the head pressure falls to 215 psi, the pressurestat again closes the circuit returning the system to normal operation.

With the separate engine drive, certain safety devices are necessary for the protection of the engine. It is necessary that the engine be protected against low oil pressure and high coolant temperature. Safety switches designed to open the engine ignition circuit are used combined with a warning pilot light to notify the driver of the occurrence.

Accessories

The equipment should be equipped with efficient air filters in order to remove dust and pollen from the incoming air and also to keep the evaporator surfaces clean. Permanent type filters of the viscous coated wire maze type are used.

As a protection against the dangers of an explosion in the event of fire, a fusible or rupture plug at the receiver is desirable.

If you searched this chapter for something which was not found in it, please let the editors know.

70. PASSENGER SHIPS

HE present day demand for travel comfort, plus the increased competition om the air lines, makes air conditioning andatory for the modern passenger ship. ll post-war constructed passenger ships e extensively air conditioned. Passenger ips constructed prior to the war have lded air conditioning to many of their baces upon reconversion.

Whereas air conditioning was previously tted into a ship after all other machinery nd services were assigned, today it is genrally recognized by the Naval Architect nd Marine Engineer that consideration hould be given to the air conditioning lant in the initial stages of design.

The following are some of the spaces rovided with air conditioning on modern assenger liners: passenger staterooms, fficers' and crew's quarters, dining rooms, fficers' and crew's mess, smoking rooms, ance pavillion, theatre, game room, ounge, library, hospital ward, operating oom, doctor's office, purser's office, stewrds' office, beauty parlor, barber shop, print shop, and children's playroom.

The design of air conditioning systems or passenger ships presents problems far nore serious than usually encountered shore. The compactness of ship accomnodations, combined with the complex structure of a ship, involves many probems which affect not only the selection of the equipment, but also the design. The subdivision of the hull into a number of watertight compartments necessitates the employment of a multiple number of fan systems in order to avoid the penetration of these watertight bulkheads wherever possible.

S. W. Brown, Author Chapter 70. Born in New York, N.Y. Educated at College of City of New York, BME, 1937. Formerly, Development Engineer, Carrier Corp., Syracuse, 1937–39; Sales Engineer, Quinn Engrg. Co., New York, N.Y., 1939–41; Application Engineer, Marine Dept., Carrier Corp., New York, N.Y.. 1941–43; Chief Engineer, 1943 to date.

Author of several technical articles, including "Modern Developments in Marine Refrign.," presented before ASRE, 1947.

Member, Amer. Soc. of Refrig. Engrs.; ASHVE; Soc. of Naval Architects and Marine Engrs.; Joint Committee for ASRE Standard, "Recommended Practice for Mech. Refrign. Installations on Shipboard."

At present, Chief Engineer, Marine Department, Carrier Corp., New York, N.Y.

General Considerations

Factors to be considered in the design of an air conditioning plant for shipboard are as follows:

I. The plant should be designed to function properly under conditions of roll and pitch to which a ship is normally subjected.

II. The materials of construction should be suitable to withstand the corrosive effects of sea air and sea water.

III. The system should be designed for uninterrupted operation during the voyage. Since ships en route cannot be easily serviced, even from land based planes, some standby capacity, spare parts of all essential items and extra refrigerant charges should be carried.

IV. The system should be designed so that there will be no objectionable noises or vibration. Although the ship's engines and auxiliaries may veil the noise and vibration of the air conditioning system while in voyage, it must be realized that the engines and auxiliaries are shut down while the ship is in port and that the noise level under port conditions must be within the acceptable limits established for land practice.

V. In view of the high premium for space on shipboard, the equipment should be designed to occupy a minimum of space commensurate with cost and reliability. Weight should be held to a minimum.

Air Distribution

The problem of providing draftless air distribution on shipboard requires careful study, because of the relatively low headroom and other construction requirements

of a modern ship, such as, projecting beams, indirect lighting coves and dome-shaped ceilings. Draftless air distribution is even more difficult to achieve in staterooms, particularly where pullman berths are provided. The methods of air distribution fall into three general classifications: (1) The side wall type which includes bar type grilles and half-round diffusers; (2) The upward discharge type in which a bar type grille is generally used. This method is confined to floor mounted installations, such as, induction units; (3) The ceiling type which consists of round or half-round, square or rectangular, flush or projecting diffusers. Another method of ceiling type distribution is the perforated ceiling panel.

Design Conditions

In determining the proper outside design temperatures, consideration should be given to the intended service of the vessel. In addition to their regular itinerary, many liners frequently make off season cruises during which more severe heating and cooling loads may be encountered. The selection of the ambient design should be based upon the temperatures incurred in port rather than upon the temperatures prevalent during the voyage. In general, for the cooling cycle, outside design conditions for North Atlantic runs are 95 F dry bulb and 78 F wet bulb; for semi-tropical runs 95 F dry bulb and 80 F wet bulb, and for tropical runs 95 F dry bulb and 82 F wet bulb. For the heating cycle, 0 F is usually used as the design condition unless it is definitely known that the vessel will always operate in higher temperature climates.

Effective temperatures from 73 to 75 F are usually selected as inside design conditions for cooling cycle. Public spaces are often designed for 80 F dry bulb and 55% relative humidity. Passenger staterooms are designed for 80° dry bulb with a relative humidity of 50% or less.

Typical Air Conditioning Systems

Comfort air conditioning systems installed on shipboard are classified as follows:

A. Those serving passenger staterooms
B. Those serving crew's quarters and other similar small spaces
C. Those serving public spaces.

Various types of systems have been applied to date for passenger staterooms and

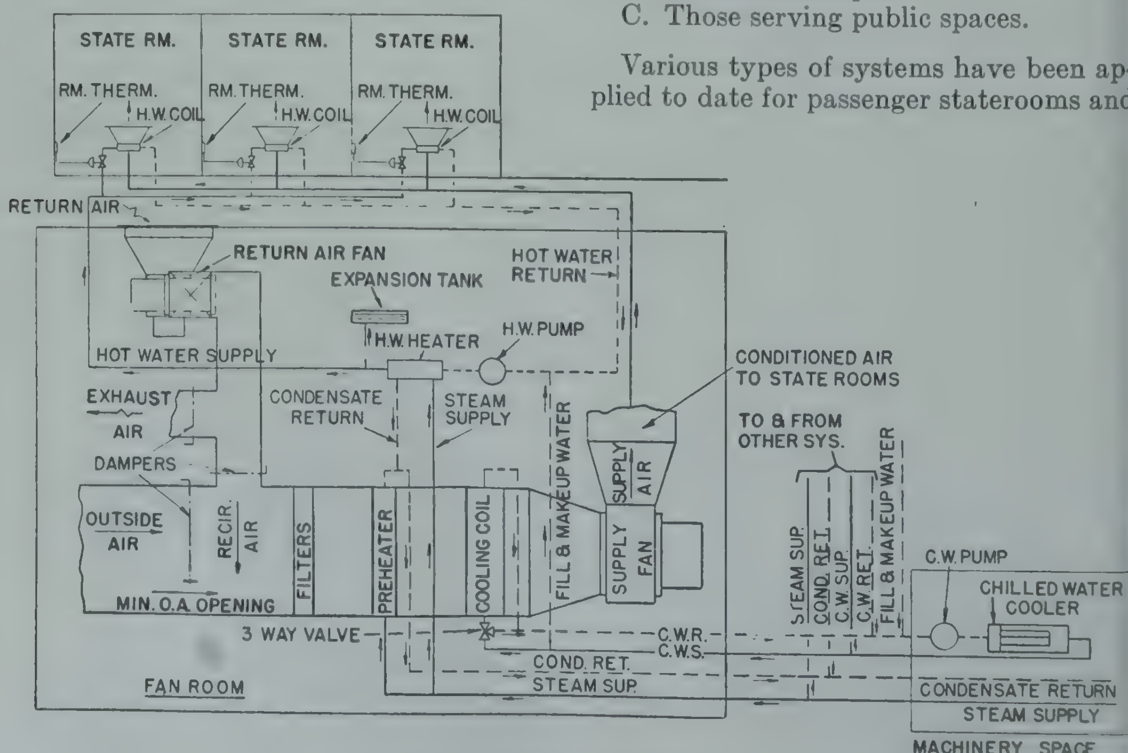

Fig. 1. Type "D" System.

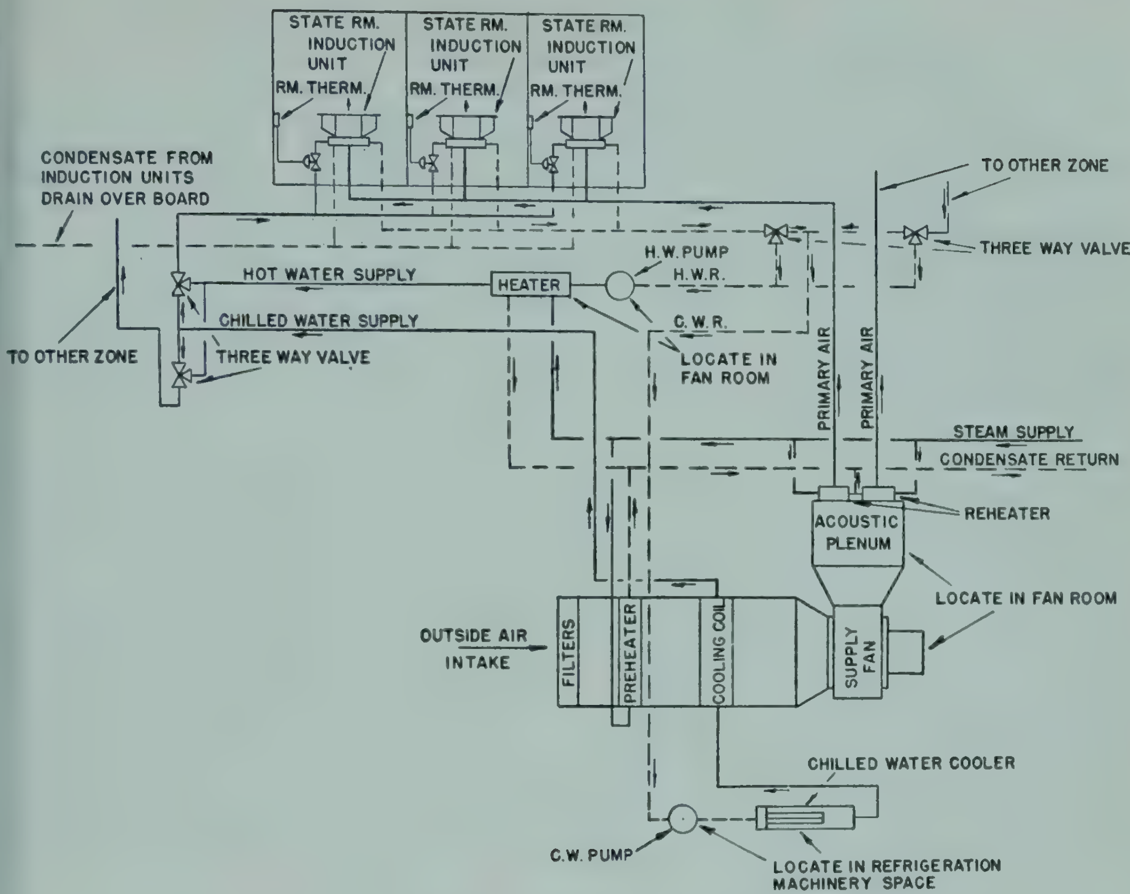

Fig. 2. Type "E" System.

crew's quarters. These are identified as follows:

1. Terminal reheat system which is commonly known as the USMC Class "D" system. A diagrammatic of this system is shown in **Fig. 1.** In this system, conditioned air is supplied to each space in accordance with its maximum design load requirements. The room dry bulb temperature is controlled by means of reheat in which a room thermostat automatically controls the volume of warm water passing through the reheat coil which is provided for each controlled space. In this system a mixture of fresh and recirculated air is circulated through the ductwork to the conditioned spaces. A minimum of fresh outside air is mixed with return or recirculated air in a central station system where it is filtered, dehumidified and cooled by the chilled water cooling coils, and distributed by the supply fan through conventional ductwork to the spaces treated. Automatic dampers are frequently provided to increase the outside air to a maximum of 100% as the load falls off. In accordance with usual practice, no recirculated air is permitted for operating rooms and hospital spaces. When 100% outside air only is used, the system is designated as Class "D1." When heating is required, the conditioned air is heated at the central station to a predetermined temperature. In addition, hot water is circulated to the reheat coil to provide additional heating capacity, as required to maintain the desired room temperature.

2. A second type of system for passenger staterooms and other small spaces is the Conduit Weathermaster system which is designated as the Class "E" system by the USMC. In this system, shown in **Fig. 2,** a central station is provided for conditioning the primary air only. The primary air is circulated to induction units located

in each of the spaces to be conditioned. The induction nozzle, through which the primary air passes, induces a fixed ration of room air to flow over a water coil and mix with the primary air supplied to the unit. The mixture of fresh air is then discharged to the room through the supply grille. The room air passing across the water coil is either heated or cooled, as required. The flow of water to the water coil can be controlled either manually or automatically to maintain the desired room conditions. In this system, no return or recirculated air ducts are required, since only a fixed amount of fresh air need be conditioned at the central station equipment. This small amount of conditioned air, which is cooled to a relatively low dew point, is circulated at high velocity and at high pressure through small ductwork, thus reducing very substantially the space required for the air distribution.

When heating is required, the primary air is heated in the central system to a predetermined temperature. In addition, hot water is circulated to the induction units to provide additional heating capacity, as required to maintain the desired room temperature.

3. A third type of system used for small individual spaces employs reheat with induction units **(Fig. 3)**. The primary air, which is filtered, cooled and dehumidified to a relatively low dew point in the central station system, is distributed through a duct system at moderately high velocities and pressures to the staterooms or individual spaces which are equipped with induction units. The primary air, in passing through the nozzle in the induction unit, induces room air to pass over a hot water reheat coil. A room thermostat automatically controls the flow of hot water to the heating coils to maintain the desired room temperature. In this system, as in the terminal reheat system, the conditioned air must be cooled sufficiently to maintain the required room conditions under the maximum design load. Therefore, reheat is required when the load is less than the maximum design. With this system, the primary air may be cooled to a relatively low temperature, since it is mixed with warmer room air at the induction unit be-

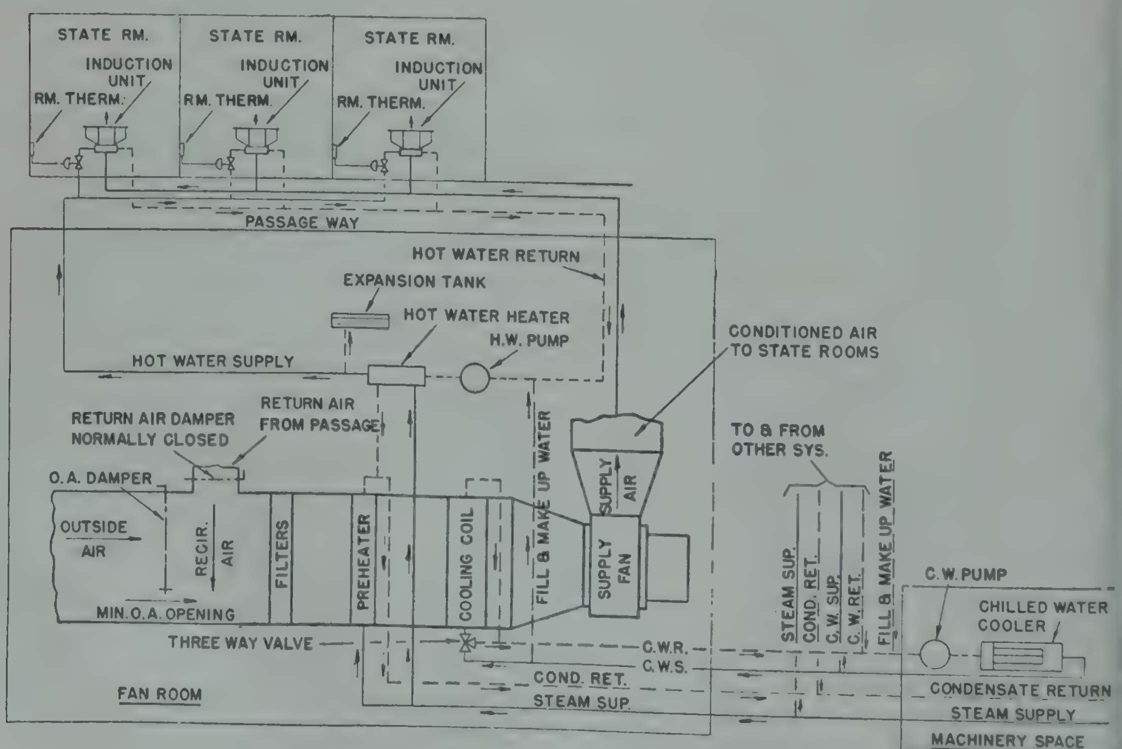

Fig. 3. Reheat System with Induction Units.

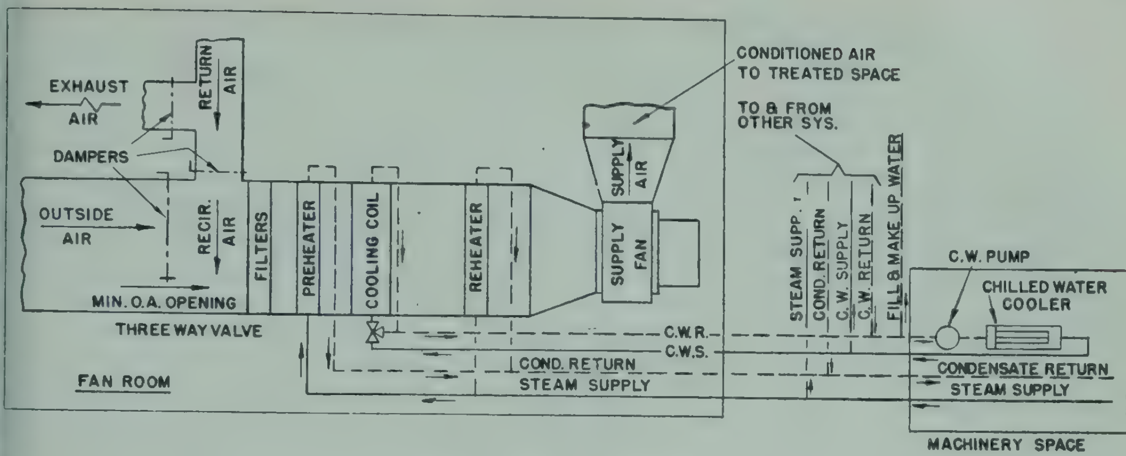

Fig. 4. Type "A" System.

fore the mixture is discharged into the room. Accordingly, the quantity of air circulated through the ductwork can be substantially reduced, resulting in the use of smaller duct sizes. When heating is required, the primary air is tempered in the central station system to a predetermined temperature. In addition, hot water is circulated to the induction units to provide additional heating capacity as may be required to maintain the desired room temperature.

Public Space Systems

Central station systems of either the built-up type or factory-assembled fan coil type are generally employed for large public spaces. **Fig. 4** is a schematic diagram of a typical public space system classified by the USMC as a type "A" system. (Under certain conditions, it is found desirable to use all outside air and avoid the use of return ducts. Where all outside air is used, the system is designated as a USMC type "A1" system.) Outside air and return air are filtered, cooled, and reheated as required at the central station unit. A room thermostat controls a modulating valve to regulate the flow of steam to the reheat coil and maintain the desired room temperature. During the heating cycle, the dampers are arranged to admit 100% outside air which is filtered and preheated at the central station apparatus and reheated as required by the room thermostat.

Ventilation Requirements

Ventilation requirements for passenger vessels generally exceed acceptable standards for land practice. Copious amounts of fresh air are desirable to eliminate odors from the bilges, engine room, from fueling and from cargo.

In public spaces, a minimum of 12.5 cfm, per person, of fresh air is provided. The quantity of fresh air is automatically increased to 100% on light loads. On the Class "D" system, a minimum of 12.5 cfm, per person, of fresh air is supplied. Here again, the outside air is increased to a maximum as the load decreases. All outside air is used on the heating cycle. However, it is customary to reduce the fan speed to circulate only 50% of the air. With the reheat type induction unit system, which can be designed for either all outside air or a mixture of recirculated and outside air, a minimum of 12.5 cfm, per person, or a minimum of a 30 minute air change, whichever is the greater, should be provided. When the system is designed to recirculate a portion of the air, automatic controls are arranged to increase the quantity of outside air as the load decreases. A minimum of 25 cfm, per person, of fresh air should be supplied for the conduit induction unit system.

Filters

Soot from the stacks which may be swept into air intakes and other air-borne dirt should be removed to prevent it from entering into air conditioned spaces. Suitable marine type filters should be installed so that the dirt may be extracted from the air before it passes over the heating and cooling coils where it is likely to accumulate

and cause operating and maintenance difficulties.

Automatic Controls

A ship, on a single voyage, may encounter extremes of climates—sometimes even within an hour. As a result, the air conditioning load on a ship varies over a wide range in a short period of time. Therefore, not only must the refrigeration plant successfully meet these variations in load, but the automatic controls must also be designed to readily adjust the system to sudden climatic changes. Accordingly, it is the general practice to equip the plant with the necessary automatic controls of the pneumatic type. Inasmuch as body comfort is a matter of individual taste, it is desirable to provide room thermostats in staterooms which can be adjusted by the occupant to suit personal requirements.

Types of Refrigeration Systems

Refrigeration machinery generally used on passenger vessels falls into two categories: (1) Freon-12 reciprocating compressors for capacities under 100 tons; (2) Centrifugal compressors for capacities in excess of 100 tons.

Some combination passenger and cargo ships fitted with considerable refrigerated spaces have used multiple duplicate compressors in which one of the compressors serves as a standby for the refrigeration as well as the air conditioning system.

Steam jet refrigeration has been used on foreign passenger liners, but has never been applied to any American passenger vessel. A new type of absorption machine designed for chilled water service, utilizing either low pressure or high pressure steam

Fig. 5. Typical Cabin Class Stateroom with Pullman Berth on S.S. "Lurline." Equipped with perforated ceiling distribution.

Fig. 6. First Class Lounge and Theatre on S.S. "Lurline."
Conditioned air is distributed through full round ceiling diffusers and perforated ceiling panels.

with lithium bromide as the absorbent and water as the refrigerant, offers many interesting possibilities for shipboard application.

Regulatory Bodies

Vessels constructed in U. S. yards which are to operate under the U. S. flag come under the jurisdiction of the U. S. Coast Guard. Accordingly, the air conditioning equipment must conform to the Marine Engineering Rules and Marine Standards of the U. S. Coast Guard. The design of the equipment and the installation must also comply with the requirements of the U. S. Public Health Service. This involves principally the rat-proofing of all openings into the ventilating system. Although air conditioning installations do not ordinarily come under the cognizance of the American Bureau of Shipping, equipment should be manufactured wherever possible to comply with the American Bureau of Shipping Rules and Regulations. ASRE Standard 26, "Recommended Practice for Mechanical Refrigeration Installation on Shipboard," provides a guide for the installation of air conditioning equipment.

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71. AIRPLANES

AIR conditioning equipment is now installed in commercial and military airplanes. Refrigeration is included for cooling and dehumidifing the compressed ventilation air supplied during flight to the cabins of commercial planes that are arranged for cabin pressurization. The compressed ventilation air supplied to the cockpit of the high speed military fighter aircraft is refrigerated to avoid otherwise unbearable conditions. Cabin cooling at the airport is accomplished by operating the refrigeration equipment installed in the plane or by the use of portable refrigeration units, or a central cooling system arranged for flexible duct connection to the plane body.

Perishable fresh and frozen food cargo space for many shipments is refrigerated at the airport during loading and, under certain conditions, during flight.

The design and application of the air conditioning and refrigeration equipment is special to meet the severe limitations of minimum size and weight. The controls are sensitive and so connected that close regulation is obtained under the rapid and extreme variations in ambient temperature, humidity, solar and internal heat gain. Heat added to the ambient ventilation air during cabin pressurization, together with the heat generated by the ram air effect from high speed, is removed by refrigeration.

There is a general opinion that aircraft do not require refrigeration because at high altitude the ambient temperatures are low. This is partly true for those planes not having pressurized cabins, but does not apply when the ventilation air is reduced in quantity and compressed by blowers in order to maintain desired cabin pressures under controlled exhaust relief.

Ambient temperatures below 75 F are sometimes not encountered before reaching 7000 feet elevation.[1] When this 75° air is used for cooling in a non-pressurized cabin, it enters the cabin at about 80 to 90° depending upon the plane speed and the resulting air ram temperature increase effect. This higher entering air temperature requires objectionable air movement in the cabin in producing the desired cooling effect.

The adiabatic temperature rise of the ventilation air and the outside air adjacent to the cabin wall can be determined from the equation:

$$T = \frac{V_p^2}{2gJC_p}$$

where:

T = temperature rise, degrees F
V_p = velocity of plane, feet per second
g = acceleration due to gravity, ft/sec/sec/
J = mechanical equivalent to heat, ft lb/btu
C_p = specific heat of air at constant pressure, Btu/lb/deg F

Applying the above equation to a free air temperature of 100 F the temperature rise from ram effect can be shown as follows:

True Air Speed MPH	Free Air Temp F	Ram Temp Rise F	Total Temp of Ram Air F
100	100	1.8	101.8
200	100	7.2	107.2
300	100	16.2	116.2
400	100	28.6	128.6
500	100	44.7	144.7
600	100	64.4	164.4
700	100	87.7	187.7

HENRY G. STRONG, Author Chapter 71. Born in Louisville, Ky. Educated at University of Kentucky, BME, 1914. Formerly, Sales Engineer, Amer. Radiator Co., 1914–17; Master Engineer, 17th U.S. Engineers (Ry.) AEF, 1917–19; Construction Supt., P. M. Sterling Co.; Sears, Roebuck Co.; independently, 1919–28; Branch and District Mgr., Carrier Corp., New York, Kansas City, Chicago, and Detroit, 1928–45; Transportation specialist, 1945 to date.

Member, Amer. Soc. of Refrig. Engrs., Chairman, Central New York Section; Member, ASHVE, Chairman, Central New York Chapter; Member, Tau Beta Pi; registered professional engineer in New York and Michigan.

At present, Specialist on Transportation Air Conditioning and Refrigeration, Carrier Corp., Syracuse, New York.

Design Conditions

Airline transportation has been presented to the public as a superior means of travel; the air conditioning equipment must therefore, produce conditions in the commercial passenger planes at least comparable to that now provided in competitive forms of travel under all conditions.

Cabin temperatures of 73 to 75 F dry bulb and relative humidity of 50% with an air motion of 15 to 25 ft about the body and no heat loss or gain to the surrounding surfaces, are found to be satisfactory.[2] Reduction of cabin air pressure with the increase of plane altitude, is held to a minimum by compression of the ventilating air. The structural design of the plane, in general, limits this pressurization to between 5 and 6 per sq in. internal or bursting pressure above the pressure surrounding the plane cabin. This pressurization permits maintaining sea-level pressure in the airplane up to an altitude of approximately 12,000 ft.

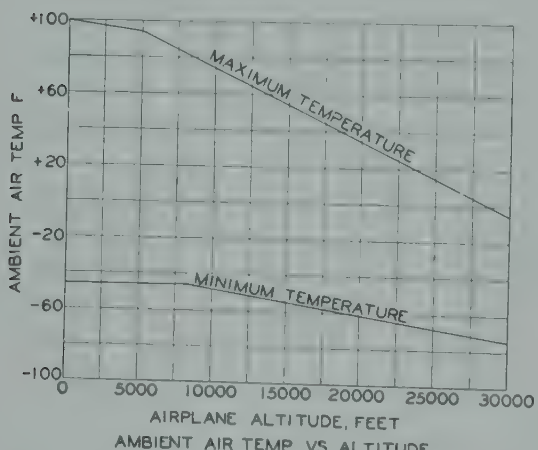


Fig. 1. Ambient Air Temperature vs. Altitude.

Ambient temperatures vs. altitude generally used in airplane design are shown in **Fig. 1.**[2]

The ventilation rate required for minimum oxygen supplied to passengers in a reduced air pressure cabin is estimated at 5 cfm at 5000 ft elevation, increasing to 7 cfm per person at a cabin pressure equivalent to 8000 feet elevation. These ventilation rates result in a carbon dioxide concentration not exceeding 5% volume at 8000 feet altitude pressure.[2]

Variation in cabin air pressure and the rate of such pressure changes are held to a minimum for passenger comfort. Government regulations limit the maximum rates on which such changes can be imposed upon the passengers. Increasing cabin air pressure while the plane is descending is most critical and causes the greatest ear discomfort to the passengers.

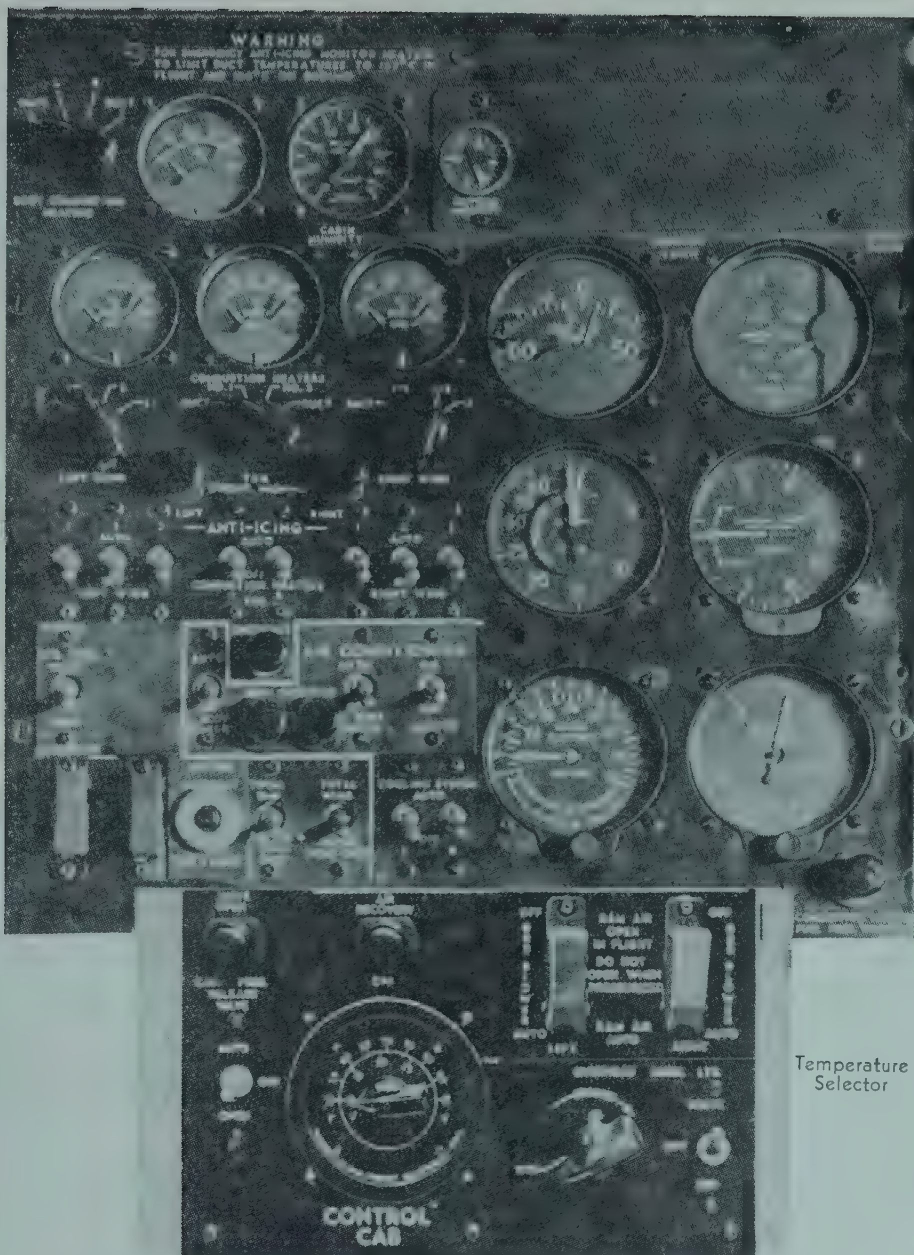
In non-pressurized commercial planes the maximum flying height is generally limited by the reduced cabin air pressure, and the rate of descent is controlled to not exceed 400 ft per minute for reasonable passenger comfort. Planes with pressurized cabins are provided with manual and automatic pressure controls whereby the cabin pressure and the rate of cabin pressure changes are maintained within known limits, and relatively independent of the plane rate of ascent and descent. **Fig. 2** is photograph of a control panel.

Fig. 3 indicates a typical pressurized plane schedule. During hot weather short range flying, where the cruising altitude does not exceed probably 10,000 feet, the air is likely to be bumpy. Flights under these conditions are far more comfortable with pressurization and proper air conditioning in the cabin. These tend to suppress air sickness by their physiological and psychological effect.

Approximately 10 tons of refrigeration capacity is required for the proper air conditioning of a sixty passenger pressurized cabin commercial plane during summer flight. The refrigeration capacity needed for the proper air conditioning of several types of commercial planes in current use, under optimum summer conditions while grounded at the airports with full passenger load and exposed to direct sun light, is considered to be:

Plane	Number of Passengers	Refrigeration Needed
Stratocruiser	60 to 75	17 tons
Constellation	43 to 60	12 tons
DC-6	55 to 58	12 tons
Convair	40	10 tons
Martin 202	36	10 tons
DC-4	34 to 50	10 tons
DC-3	21	8 tons

Portable truck mounted units, using



Boeing

Fig. 2. Air Conditioning System Controls.

either engine driven direct expansion Freon systems or ice, are used at the airports to supplement the cooling equipment carried in the pressurized planes, or to cool the non-pressurized planes. A central cooling system supplying conditioned air through underground piping and suitable roadway connections, is also in use for summer cooling and winter heating.

Refrigeration Systems

Dry ice and brine, Freon direct expansion, and the air cycle system are now used for plane cooling while in flight. Refrigeration capacities vary from approximately one ton for the fighter air craft cockpit having a volume of 40 to 60 cubic feet, to capacities of 10 tons for the larger commercial pressurized planes having nearly

6000 cubic feet cabin volume and designed to accommodate about 75 passengers in comfort.

Dry ice liberates CO_2 durings its cooling cycle in quantities beyond that permissable if direct surface contact were used in a pressurized plane. Low surface temperatures of the CO_2 together with control difficulties compel the use of an alcohol solution with insulated cooling tank, circulating pumps and cooling coils. Dry ice has the advantage that its cooling effect is positive and that it cannot fail in itself; its general use has been retarded by the known methods that must be employed in the system application and use in the airplane.

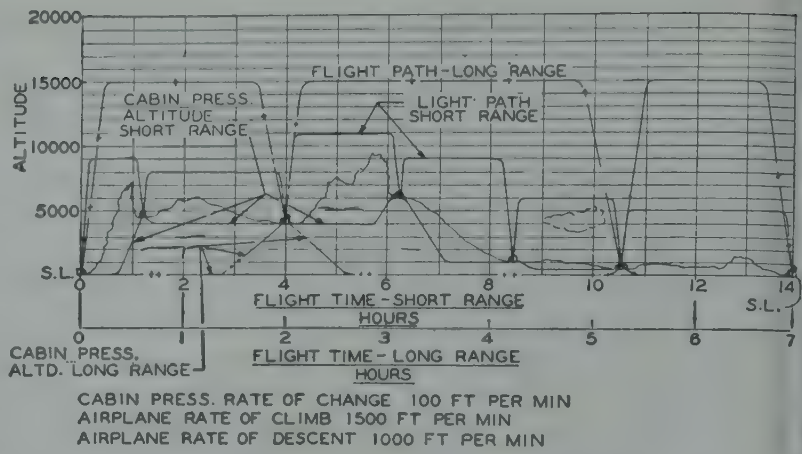


Fig. 3. Typical Operations Cabin Pressure vs Airplane Altitude.

In the air cycle system, air itself is the refrigerant. A definite quantity of air, depending upon the designed refrigeration capacity of the unit, is compressed through a high speed centrifugal compressor. This compressed air passes through an air-to-air after-cooler and enters an expanding turbine. The expanding turbine delivers power

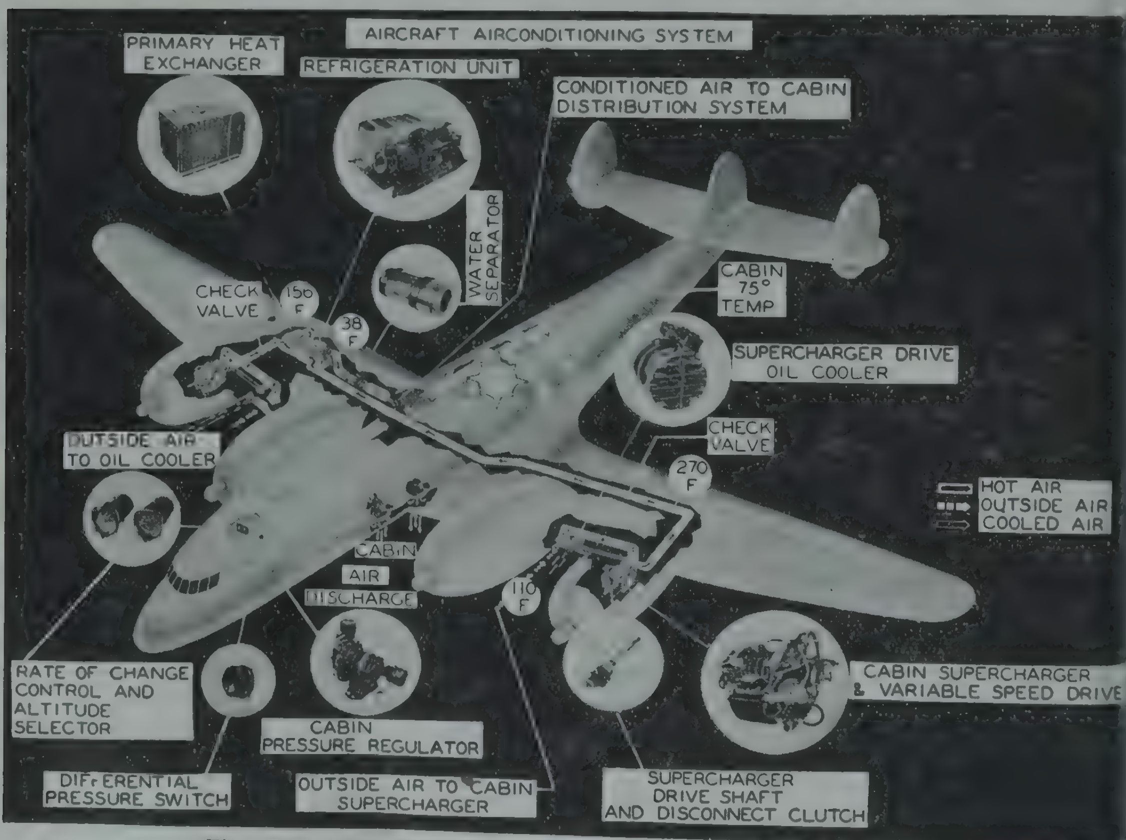


Fig. 4. Lockheed Constellation Aircraft Air Conditioning System.

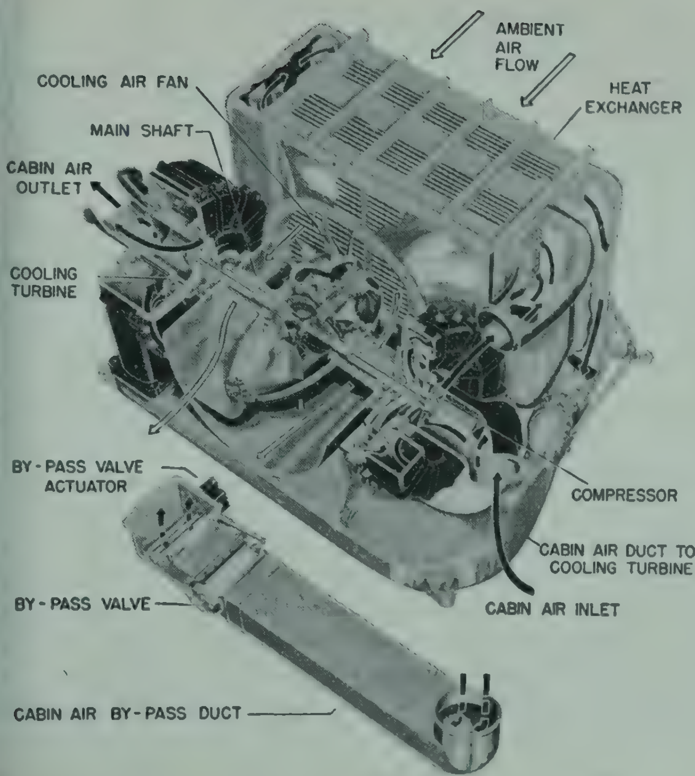


Fig. 5. Cutaway Constellation Refrigeration Unit.

to the compressor or the air fans in the system. The final expanded air leaves the turbine at the reduced pressure and temperature needed for cooling and pressurizing the plane cabin. In some of the air cycle applications the desired quantity of compressed air is drawn from the main propeller engine superchargers of the reciprocating engine system, or from the air compressor sections of turbine engines where such engines are used. The present gradual trend from reciprocating engines to turbine engines with their relatively large capacity centrifugal air compressors, is favorable to the use of the air cycle system and makes this system very attractive under such conditions. **Fig. 4** shows a sketch of the air cycle system as applied to a plane. **Fig. 5** is the refrigerating unit.

The advantages for the air cycle system lie in its use of air as a refrigerant and its minimum space and weight requirements. The amount of power required per unit of refrigeration is considerably greater than that required for the conventional liquid vapor system. This additional horsepower requirement for the air cycle is offset under certain conditions of flight by the reduction of total plane horsepower otherwise required to transport the larger and heavier liquid vapor system.[3] The absolute humidity of the air entering the air cycle system remains constant during compression and is reduced by condensation to water or snow on leaving the expansion turbine.

In the liquid-vapor system, Freon-12 refrigerant is used. The cooling and dehumidifying coils are direct expansion. The

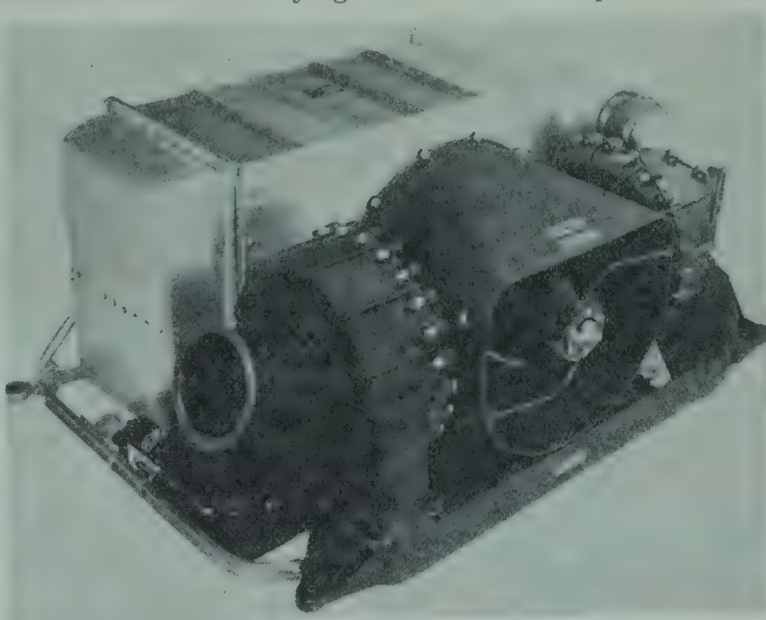


Fig. 5-A. Constellation Refrigeration Unit.
100 lb of air per min. Wt approximately 150 lb.

condensing coils are dry air cooled. All parts of the system, including the refrigerating compressor and coils, are constructed of aluminum wherever possible in order to reduce weight.

Fig. 6 illustrates a cabin air conditioning system using the Freon-12 liquid vapor system in a pressurized cabin commercial plane. In this system a high side assembly consisting of the aluminum compressor, motor, receiver and aluminum condensing coil is located in each of the two outboard nacele skates. The compressors are belt driven from direct current motors. Two direct expansion aluminum evaporator coils are independently connected to each of the condensing assemblies. The total cooling capacity of both systems is 10 tons. **Fig. 7** shows a cooling and dehumidifying unit built in to the pressurized cabin air space. This unit contains air filters, two cooling coils, activated carbon air purifiers and the motor and fan for circulating the conditioned air.

The electric motors driving the refrigeration compressors operate at constant speed. Electric power is supplied from the main engine generators during flight. Each refrigeration compressor has built into itself a capacity control that regulates its output from 100% to 50%. Both systems are interconnected into the master control system so that four steps in system operation from minimum cooling output to the maximum cooling output can be obtained.

With the Freon cycle the air conditioning and the cabin pressurization system each have separate controls and operate independently of each other. During pressurized flight the engine supercharges supply the incoming air to the air conditioning units. During flight where pressurization is not required ram air is forced into the system. At the airport the air conditioning system can be operated by plugging in electric current connection. Electric driven blowers, built into the plane, draw needed outside air into the air conditioning system

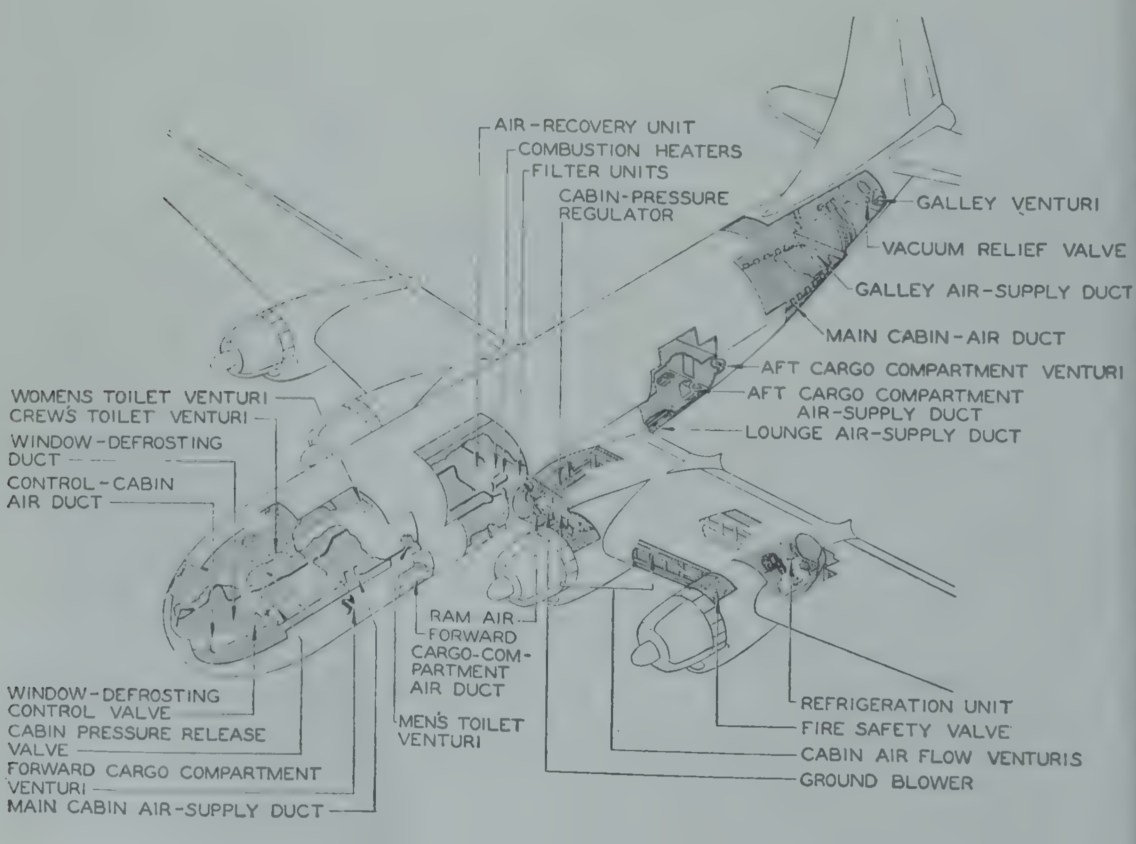


Fig. 6. Freon-12 Cabin Air Conditioning System. (Boeing)

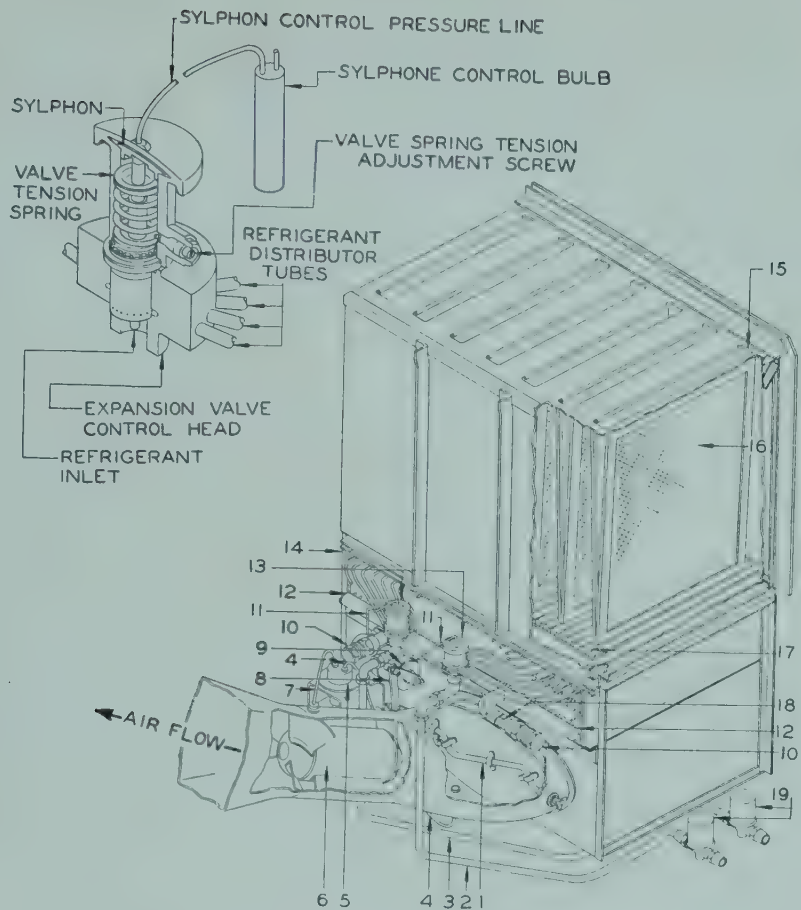


Fig. 7. Freon-12 Air Conditioning Unit. (Boeing)

similar in the manner to that employed in conventional air conditioning installations.

The advantages of the Freon system are its minimum horsepower requirement and ability to produce controlled temperature and humidity conditions in the plane when operated in connection with the plane heating system. The Freon system permits easy and convenient operation while loading and discharging passengers at the airport. The disadvantages of the Freon system lie in the fact that a refrigerant gas must be employed and in the increased overall space requirement and the weight of the system.

An increasing number of cargo planes are being equipped to accommodate dry ice or water ice for the protection of perishable cargo while loading and during flight. Some pilot experimental mechanical systems are in use. In general, however, cargo precooling and the use of terminal ground transport refrigeration facilities have proven most practical.

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3. Scofield, Paul C. Air Cycle Refrigeration. *Refrig. Eng.*, pp. 558–563, June 1949.

If you searched this chapter for something which was not found in it, please let the editors know.

SECTION VIII

INDUSTRIAL AIR CONDITIONING

F. H. Faust, Associate Editor. Born 4/11/05 in Salt Lake City, Utah. Educated at Sheffield Scientific School, Yale University, B.S., 1926; General Electric advanced engineering course and courses in heating, air conditioning, sales analysis and better business management; Harvard University, School of Medicine, course in Industrial Physiology; Case School of Applied Science, course in air conditioning.

Formerly, Assistant Instructor, Yale University, 1926; General Electric Company, Testing Dept., 1926–28; Domestic Refrigerator Engineering Div., 1928–29; Commercial Refrigerator Engineering Div., 1929–31; Engineering General Dept., 1931–32; Air Conditioning Dept., Commercial Engineer, 1932–47; Manager of Commercial Engineering Div., 1947–49; Manager of Trade Relations, 1949 to date.

Author of Chapter on "Unit Air Conditioners" in ASHVE Guide; Associate Editor Section VIII and Author Chapter 67, 1946. Applications Volume, ASRE Data Books; Editor-in-Chief, Handbook of Oil Burning, 1951; Author of articles on "Air Conditioning" and "Heating and Ventilating" in Encyclopedia Britannica Book of the Year; Author of papers on Heat Pumps, Heat Gain, Selection of Air Conditioning Equipment and others presented to ASME, ASHVE, and ASRE and published in the journals of these societies. Fellow, Amer. Soc. of Refrig. Engrs.; Member, Joint Committee for Rating Refrigerating Equipment; Chairman, Technical Committee on Air Conditioning, 1940; Member, Program and Membership Committees, 1941; Council, 1941–46 and 1949–50; Vice-Chairman, Committee on Revision of ASRE Standard 16, 1946–49. Member, Amer. Soc. of Heat. and Vent. Engrs and representative on Joint Committee for Rating Commercial Refrigerating Equipment, 1934–47; Chairman, Committee on Air Conditioning, National Fire Protection Assn.; Engineering Committee of Oil Heat Institute of America 1942–49; General Engineering Committee, Air Cond. and Refrig. Machinery Assn., 1949–50. Member, Technical Committee on Fuel Oil Specifications and Chairman of a subcommittee of Amer. Soc. for Testing Materials. Vice-chairman, Code Drafting Committee, Amer. Standards Assn., Safety Code for Mechanical Refrigeration, B-9.

Received citation from J. C. Krug, Chairman, War Production Board, for work as member of several Industry Advisory Committees; "Aladdin's Lamp" of Oil Heat Institute of America; Tau Beta Pi, Honorary Scholastic Engineering Fraternity.

At present, Manager, Trade Relations, Air Conditioning Dept., General Electric Co., Bloomfield, N. J.

Chapter **Page**

72. INDUSTRIAL AIR CONDITIONING

Outline of Applications

In the **storing** and **processing** of materials air conditioning may be required:

1. To control the moisture content.
2. To control the rate of chemical and biochemical reactions.
3. To prevent corrosion of metals and deterioration from rot, mildew, etc.
4. To control the rate of crystallization.
5. To eliminate or reduce the hazards of static electricity.

In **precision manufacturing** air conditioning may be required:

1. To limit the variations in dimensions of tools, gages, and materials resulting from fluctuating temperatures and humidities so as to permit manufacturing and assembly to close tolerances.
2. To control the quality of air, to avoid spoilage and rejects from dirt particles and to remove from air any particles or gases harmful to health.
3. To reduce corrosion resulting from perspiration on workers' hands or resulting from high humidity in the air.

In **laboratories** and in testing, air conditioning may be required to simulate atmospheric conditions for testing equipment, instruments and personnel. Such applications are particularly important in aviation.

Work efficiency dictates the use of air conditioning in warm weather. This is especially true where heat gain is high due to industrial processes, machinery, lights or people. The problem is accentuated in windowless buildings, but fortunately air conditioning can usually be added for only a moderate increase in first cost of a good system of ventilation.

Health and comfort are improved with industrial air conditioning. However, in most industrial applications air conditioning is usually designed for processing requirements or for precision manufacture or work efficiency and the benefits to health and comfort are incidental. Despite this fact, health and comfort requirements should be recognized in designing the system, because it is possible to adjust the required air conditions in many applications to provide a reasonable compromise between the requirements of the process and the comfort and health of people.

Safety is increased by air conditioning because of the reduction in fatigue and the hazard of explosion due to static electricity. The reduction in explosion hazard from static electricity is particularly important in printing plants, textile plants and hospital operating rooms.

Scope of Chapters

The chapters of Section VIII discuss the more important industrial applications. In addition this chapter discusses general requirements.

Industrial air conditioning and industrial refrigeration are oftentimes very close together so that, practically, it is difficult, if not impossible, to separate them for discussion. In general, industrial air conditioning involves the treatment of air as regards its temperature, humidity, quality and motion, whereas industrial refrigeration involves the treatment of a product. In the chapter on "Man-Made Textile Fibers" it was not feasible to separate these two types of applications, so they are both included. However, where practicable, the subject matter has been limited to air conditioning as explained herein.

Applications of air conditioning have generally been selected only if they involve refrigeration. However, in some cases, it is possible to obtain equivalent results by humidifying, dehumidifying or heating in conjunction with humidifying. For the

Frank H. Faust, Associate Editor Section VIII and Author Chapter 72.

sake of completeness some of these applications are considered.

The list of industrial air conditioning applications does not include all applications which could be called air conditioning; for example, industrial humidifying and evaporative cooling. Another application not included is **drying** with heating, as used in many operations such as the manufacture of lead pencils, flour, drying lacquers and shoes.

Applications of air conditioning in such places as **libraries** and **hospitals** may be questioned as to whether they are properly commercial or industrial air conditioning. In the case of libraries the proper preservation of books is of equal if not greater importance than the comfort of readers; hence it is included in this section. Air conditioning in hospitals involves special requirements for health and safety in operating rooms and for special medical treatment. This seems to justify treatment in this section rather than under commercial air conditioning.

Air conditioning is applied to a few **foods,** notably bread, lemons, potatoes (white and sweet), all of which require a relatively high storage temperature. Food freezing and preservation are usually considered to be applications of refrigeration rather than of air conditioning. Also because of their importance, they are treated in separate sections of this book.

Moisture Content

Hygroscopic materials are those that readily absorb and retain moisture. They are generally of vegetable or animal origin, although to some extent minerals in certain forms are also hygroscopic.

The temperature and relative humidity of air affect the hygroscopic moisture content of these materials and in turn their weight, strength, appearance, quality and ease of working. The control of hygroscopic moisture may be required during manufacture or storage to permit easy processing and to fix the weight at the time of shipment when the product is sold on a weight basis or when quality is affected.

Moisture content is the sum of free moisture (resulting from submersion or wetting) and hygroscopic moisture, which is moisture absorbed from the atmosphere.

Table 1. Moisture Content by Weight (Regain) of Hygroscopic Materials at 75 F*

Relative humidity, %	Leather	Leaf tobacco	Wood	Paper, kraft	Flour	Rayon	Glass wool	Kiesel-guhr
10		7.40	3.0	3.25	2.20		.10	.31
20	12.0	10.80	4.4	4.70	3.90		.15	.67
30	13.75	13.90	6.0	5.70	5.05	8.75	.19	.82
40	15.05	16.35	7.6	6.65	6.90	9.90	.22	1.10
50	16.90	19.50	9.3	7.70	8.50	11.10	.22	1.37
60	17.45	23.00	11.3	8.95	10.08	12.50	.23	1.67
70	18.85	27.10	13.9	10.60	12.60	15.00	.25	2.00
80	22.60	33.40	17.8	12.65	16.80	19.00	.30	2.55
90	31.00		23.8	14.90	19.00	24.80	.40	3.22

	Cotton	Wool	Silk	Crackers	Bread	Macaroni	Gelatine	Starch
10	2.5	4.7	3.2	2.1	0.5	5.1	0.7	2.2
20	3.7	7.0	5.5	2.8	1.7	7.4	1.6	3.8
30	4.6	8.9	6.9	3.3	3.1	8.8	2.8	5.2
40	5.5	10.8	8.0	3.9	4.5	10.2	3.8	6.4
50	6.6	12.8	8.9	5.0	6.2	11.7	4.9	7.4
60	7.9	14.9	10.2	6.5	8.5	13.7	6.1	8.3
70	9.5	17.2	11.9	8.3	11.1	16.2	7.6	9.2
80	11.5	19.9	14.3	10.9	14.5	19.0	9.3	10.6
90	14.1	23.4	18.8	14.9	19.0	22.1	11.4	12.7

* Wilson, R. E. and Furva, J., Industrial and Engrg. Chemistry, 14, 943, 1922.

t is usually expressed as the percentage of he total weight of material.

Regain is the hygroscopic moisture only, xpressed as a percentage of the bone-dry veight of the material. It is the moisture ontent that results from absorption of noisture from the atmosphere. It does not nply that the material has been dried rior to absorption of moisture. As a rule rying to bone-dry condition is unwaranted because it impairs the life, strength nd quality of the material.

Table 1 shows the regain of hygroscopic naterials at 75 F for relative humidities anging from 10 to 90 percent.

The most desirable atmospheric conditions for processing depend upon the product and the nature of the process. Humidiies in excess of 50 percent increase the oftness and pliability and decrease static lectricity and atmospheric dust from the roduct. Lower relative humidities are required where drying of the product is a facor.

The term drying is usually used when he final moisture content is lower than the nitial one, and the term conditioning when the final moisture content is higher than the initial one.

The effect of temperature on hygroscopic materials is relatively unimportant compared with the effect of relative humidity. An increase in temperature of 10 F has the same effect on regain of a material, such as cotton, as a decrease in relative humidity of one percent. This, however, does not imply that regulation of temperature is unimportant because it may need to be controlled for other reasons. Also, it has an important effect on the comfort, health and efficiency of workers. Specific requirements for regain in storage and processes are given in the chapters in this section on Storage and Processes, Printing Plants, Man-Made Textile Fibers and Libraries and Art Museums.

Chemical and Biochemical Reactions

The control of temperatures is used as a means of controlling the rates of chemical reactions. In biochemicals it is used as a means of controlling the rate of growth of molds, fungi, bacteria, etc. The control of relative humidity is required as a means of maintaining a constant rate of evaporation or as a means of drying. In addition to the control of regain, air conditioning is used, as, for instance, in rayon manufacture, for the control of chemical reactions. Air conditioning is used in the biochemical field to control the development of yeast fermentation and for curing certain types of food.

Crystallization

Air conditioning is required for **coating** medicine, candy and gum. The size of the sugar crystals and the appearance of the coating is affected by the rate of cooling of a saturated sugar solution. The proper amount of air supplied at the correct dry and wet bulb temperatures is necessary to control the rate of cooling and the rate of evaporation.

Static Electricity

The hazard of explosion due to **static electricity** can be reduced by holding relative humidities in excess of 50 percent and preferably about 60 percent. Humidification alone may be sufficient to accomplish the desired result; however, it is usually possible to design air conditioning equipment to produce the desired relative humidity at more comfortable temperature conditions than generally prevail in summer.

73. STORAGE AND PROCESSES

THIS chapter describes applications of air conditioning in industry where the [p]rincipal purposes are to control the mois[t]ure content of hygroscopic materials, the [r]ate of chemical and biochemical reactions, [o]r the rate of crystallization.

Ball Bearings

In the manufacture of ball bearings, air [c]onditioning is responsible in part for cut[t]ing rejections from all causes to as low as [3] percent of total production.[1] Among the [c]auses for rejection are:

1. Formation of rust on bearing parts [d]uring the manufacturing process
2. Presence of dirt and foreign matter in [a]ssembled bearing.

Air conditioning is so important in the inspection area, that when girls work they operate from behind glass shields so that their breath will not condense on the metal. Lint-free gloves are worn to prevent perspiration from reaching the finished product.

Air conditioning is used for humidity and temperature control, and to produce dustless air in the assembly, final inspection and packing areas. Air is held at 34 to 36 percent relative humidity and 74 F temperature. While it is possible to use a lower relative humidity, workers would complain of dryness in the nasal membrane.

As fast as work is completed, it is stored in a small closed room maintained at 110 to 120 F and at 10 percent relative humidity. Only enough parts are taken at one time from the hot room as can be finished, assembled or packed within a few hours.

Where parts are warmer than the surrounding atmosphere, no rust will form on the parts. During summer months, about one percent rejects result from perspiration causing rust spots on the metal.

Bananas

Wholesale banana dealers require ripening and storage rooms in order to supply retail dealers regularly with fruit in proper condition. Both heat and refrigeration are required to maintain temperature conditions necessary to regulate and control cooling and ripening of the fruit. A very high relative humidity from 90 to 95 percent is recommended. The temperature range is from a minimum of 56 F to ordinarily not more than 70 to 72 F. The use of conditioner units with direct expansion coiling is now common. Spray type units should **not** be used as the spray liquid absorbs ethylene and possibly other gases which are helpful in promoting even ripening. While it was formerly recommended that rooms be ventilated during storage, most operators at present do not consider this necessary.

Banana ripening and storage rooms will require as much as 3 to 3½ tons of refrigeration per carlot room because in ripening, bananas generate heat at a rate as high as one-half Btu per lb per hr. Furthermore, it is necessary at times, in order to control ripening, to be able to reduce the temperature of the fruit itself at a pull down rate of one degree F per hour. Thus, the refrigeration requirements for bananas are nearly as great as for rooms designed for the storage of products at 35 F.

The curing of the fruit for the market is done by wholesalers or fruit handling specialists and it involves heating if it is desired to speed up the process, and cooling to slow it down. A unit cooler or conditioner may be adopted for both purposes. The ripening temperature will be above 70 F with a high humidity—possibly 90 per-

NATHAN N. WOLPERT, Author Chapter 73. Educated at Polytechnic Institute of Brooklyn, ME. Formerly, Engineer, National Board of Fire Underwriters, 1923–28; Associate Editor, *Water Works Engrg. and Fire Engrg.*, 1928–42; Assistant Editor, *Product Engrg.*, 1942–43; Associate Editor, *Heating and Ventilating*, 1943 to date.

Author of two books in the water works field and a number of articles on air conditioning published in *Heating and Ventilating*.

Member, Amer. Soc. of Refrig. Engrs.; Amer. Soc. of Htg. and Vent. Engrs.; Amer. Soc. for Engrg. Educ.; licensed professional engineer, State of New York.

At present, Associate Editor, *Heating and Ventilating*, New York, N. Y.

cent. Heating coils should be provided for raising fruit temperature at the rate of 2 F per hour using a delivery air of not higher than 100 F. Separate electric or gas heaters are also used. The fruit is cooled again after ripening, say after 24 hours, to 68 F and then further cooled if storage is continued, as is usual to complete the ripening process at 66 F. A further means of livening up the process and making it more uniform is the use of ethylene gas in the conditioned air.

If ripening is to be carried out in five to seven days it may be done at about 64 F. Slow ripening means a period of nine or ten days at 60 to 62 F for storage.

For general storage after ripening, temperatures of 56 to 60 F are used with relative humidity of around 90 percent. The control system involves two thermostats for cooling and heating. Dampers and ducts may be controlled manually.

Bananas are shipped in coastwise vessels of 3,000 to 8,000 tons. A typical boat of this type will carry 50,000 bunches of 75 pounds each, packed in an upright position but not necessarily one layer to a hold. Sometimes the bunches are loaded in two layers and sometimes they are loaded in one layer upright and one or two layers stowed horizontally on top. The refrigeration system may be ammonia or Freon. Carbon dioxide has also been used in the past. Freon is preferred, with a forced air circulation system fed from a central coil system.

The cargo on each deck is loaded upon wooden gratings, supported on 3-inch wood risers to permit an air space for the distribution of cooled air entering the fruit compartment at the floor level, from side air ducts. Holds are always referred to as forward or aft. The aft group may consist, for example, of three holds, that is three decks, composing the entire stern half of the ship on three levels. These are known as the upper'tween deck, aft; lower 'tween deck, aft; and orlop deck, aft. The forward group has the same terminology, with sometimes a fourth or lowest, deck, known as the lower hold.

Central cooling stations for an air circulation system will be found adjacent to the refrigerating machinery room, occupying a space about 10 feet in a fore and aft direction, and extending the full width of the ship. Fans receive return air through ducts from all the spaces served. Beyond each fan are banks of refrigerating coils. As the temperatures held in banana storage are high, there is no allowance necessary for frost, making possible fins of the minimum spacing.

From the refrigerating coil, which also has equipment for heating, the air is circulated in ducts made of wood and entirely mounted on the outer walls of the holds against the insulated sides of the ship. Dampers permit closing off any of these ducts if the holds are not in use.

Blast Furnaces

The drying of air before its introduction to blast furnaces has been practiced for some time. A modern application of mechanical refrigeration has been made in two plants where large compression systems were applied. Water is removed from humid summer air by conventional conditioning apparatus which effects a more uniform rate of production and quality of iron. The amount of coke required per ton is reduced and the silicon content of the product is affected.

The furnace is a refractory lined, partially water jacketed structure, 70 to 100 feet high with a hearth up to 28 feet in diameter. The burden or mixture of ore, coke, fluxes for forming the slag, and other additions needed to give desirable contents are fed through and distributed by the bells at the top. The wind is blown through the tuyeres which enter just above the hearth. At this point the combustion of the coke generates the highest temperature which occurs in the furnace, usually about 3,000 F. Carbon dioxide is formed momentarily but as the coke is incandescent a reverse action follows almost immediately, converting the carbon dioxide into carbon monoxide which is a powerful reducing agent. As the gases ascend the stack, some of the carbon monoxide combines with the oxygen of the ore to form carbon dioxide, thus freeing metallic iron. From 10 to 12 hours elapse from the time at which the burden is charged until it is finally converted into iron and slag.

The pressures required for blowing, nor-

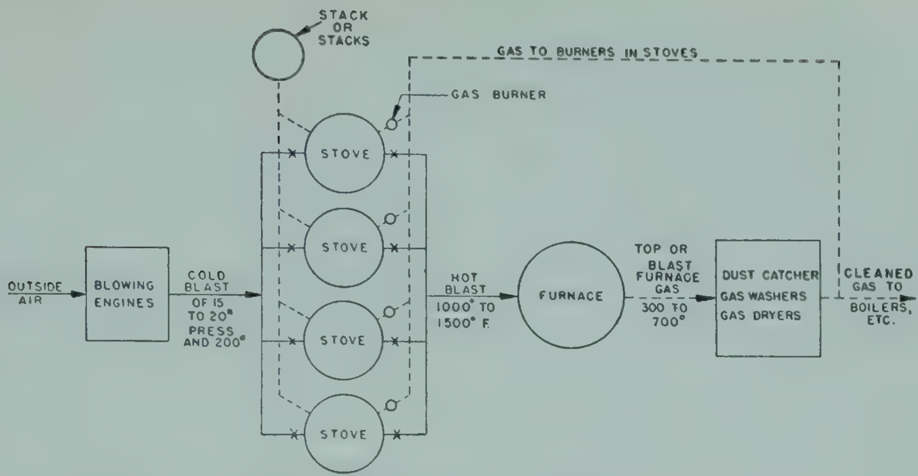

Fig. 1. Progression of Flow Through Blowing-Engines, Stoves and Furnace, and Flow of Furnace Gas.

ıally range from 15 to 20 lb gage. Turbine riven centrifugal blowers are becoming opular, but in constant use are many team and some gas driven blowing enines.

Before entering the furnace, the air is eated in stoves **(Fig. 1)**. The stove is a ylindrical steel structure lined and filled vith a checkerwork of refractory materials, eriodically preheated to suitable intensity y the combustion of blast furnace gas. Jormally the hot blast is raised to a temerature of 1,000 to 1,600 F.

The blast supplies the oxygen required or combustion of the coke and, after the everal conversions previously mentioned, he gases are taken from the stack at a evel between the bottom bell and the top f the stack column inside the furnace. These gases may contain as much as 35 perent carbon monoxide, with a calorific alue as high as 112 Btu per cu ft. As the ases flow to the top they are cooled and he charge is preheated and dried. In genral the cooler the top gases, the better.

From the uptakes the top gases flow hrough various cleaning devices such as eparators, wet washers, electric precipitaors or dryers, etc., and thence back to the toves and to boilers, gas engines, mill urnaces, etc. At the stoves they are burned n special burners to preheat those three vhich normally are cut out while the fourth s in blast. The thoroughness of cleaning is f great importance to the stoves, which quickly lose capacity when heated with dirty gas.

The variety of purposes for which blast furnace gas may be used leads to a wide variety of fuel balances. Some furnaces are compelled to waste vast volumes daily; some are able to sell excess power generated. Refrigerating the air may save more than enough power to pay for its own operation.

Commercial Photograph Studios

Photographic studios require air conditioning for personal comfort, to control the photographic finishing processes, and for the better storage of sensitized paper and film.

In the printing and developing room, not only must air conditions be controlled but it is desirable to maintain the developing solutions and rinse water at proper temperatures. The time of development and the resulting quality is directly related to these temperatures. Heat is liberated by the printing, enlarging and drying processes. This heat is removed through an independent exhaust system which also serves the lamp houses and dryer hoods.

Studio, dressing rooms and offices are maintained at 74 F and 30–40 percent rh; developing of film, 70–75 F and 60 percent rh; film drying, 75–80 F and 50 percent rh; printing, 70 F and 70 percent rh; cutting, 72 F and 65 percent rh; storage, 60 F and 45 percent rh.[2]

Electrical Conductors

The manufacture of electrical conductors to be made up into cables involves interesting examples of refrigeration. Cable circuits for long distance telephoning are insulated with paper and baked at high temperatures and under vacuum before being covered with a lead sheath. During the storage of cables after drying and before lead covering, the lowest possible moisture content is essential in the storage room. Even 10 percent relative humidity at 85 or 95 F gives unsatisfactory results. Relative humidities below 1 percent are necessary. This corresponds with dew points well below 0 F.

In the practical operation of such a system to obtain these low relative humidities, the use of adsorbers such as silica gel and lithium chloride combined with refrigeration or low temperature deep well water has been utilized. In this process, air to be conditioned is brought down to as low a temperature as necessary, either by refrigeration or by use of low temperature well water to assure maximum efficiency of the silica gel when removing moisture from the air. The air is then passed through the silica gel beds where its moisture content is reduced to a fraction of a grain per cubic foot.

Felt Goods

In the manufacture of felt hats, the principal product used is rabbit hair, a cellular substance which readily absorbs moisture. As the quality of hats is to a great extent a question of weight, an exact moisture content under all conditions is essential. The sizing in which the hair is mixed is greatly affected by temperature. Therefore in the manufacture of fine hats, uniform conditions of temperature and humidity must be maintained by the addition of refrigeration to air conditioning. In forming the hat, a definite quantity of air must be drawn through hair and glue to get results.

Jewelry

The manufacture of artificial pearls is similar to the manufacture of glass beads, but the iridescence and opaqueness of the beads are obtained by a special chemical means. This process is greatly affected by temperature and humidity in the drying room. When the pearls come out of their dipping bath, they are carried through a drying process; in order to obtain the best pearls, a uniform condition of not more than 68 F with 50 percent relative humidity is ideal.

As the amount of refrigeration depends entirely on the size of the room, rule of thumb quantities of refrigeration cannot be stated, but the problem is simpler than others in which air conditioning is combined with refrigeration. As the artificial pearls come into the room heated, allowances must be made for the amount of heat inherent in the material itself, as well as the maintenance of conditions due to the ordinary heat sources.

Laminated Glass

Safety glass consists of two sheets of glass that are held together by a plastic binder that must be kept at the right moisture content.[3,4] If this residual moisture is too high when the material is removed from the drying room, it will not adhere well to the glass. At room temperature this plastic (vinyl resin) becomes limp and tacky while at temperatures below 65 F, it is fairly stiff and easy to handle. Under humid conditions, it can absorb enough moisture to be detrimental to processing. Best conditions result when the cutting room is maintained at 65 F and 15 percent relative humidity; inspection and laminating rooms at 55 F and 15 percent relative humidity.

Leather

Refrigeration enters the leather business on the supply side in storing hides, and for the finished product in the storage of certain types of leather, notably patent leather. Such glossy surfaces tend to stick together above a temperature of about 85 F. Scratching is also minimized by cooling, as is labor for handling.

Practices for drying vegetable tanned sole leather vary with the tannery but in general over a drying period of 10 days, the temperature is increased from 70 to 90 F and the relative humidity is reduced from 75 percent to about half that value.

Laboratories for the physical testing of

ather are maintained at 73.4 F and 50 rcent relative humidity.[5]

Matches

In the match industry, the tendency to-ay is to remove moisture from the air by emical means. Many of the plants op-ate with little or no air conditioning. The sulting handicap is that in such plants on few bad days when air conditions are not st right, machines must be slowed down omewhat to allow sufficient time for dry-g.

While the preferable condition is 70–75 with a relative humidity of 40 percent, atches have been made at temperatures bove 80 F.

In the conditioning of the match plant, ot only must a definite temperature and umidity be maintained, but a large mount of water must be evaporated. Per illion matches, 18 to 20 pounds of water re evaporated simultaneously with the etting of the glue which makes up a large art of the match head. The match ma-hine, as it is understood in the industry, ill usually turn out about 750,000 matches er hour.

Mottled Ware

Mottled ware, a type of enamel coating or black iron, is greatly affected by the temperature and moisture in the drying room. Refrigeration is required as part of the air conditioning equipment, conditions being 80 F and about 70 percent rh.

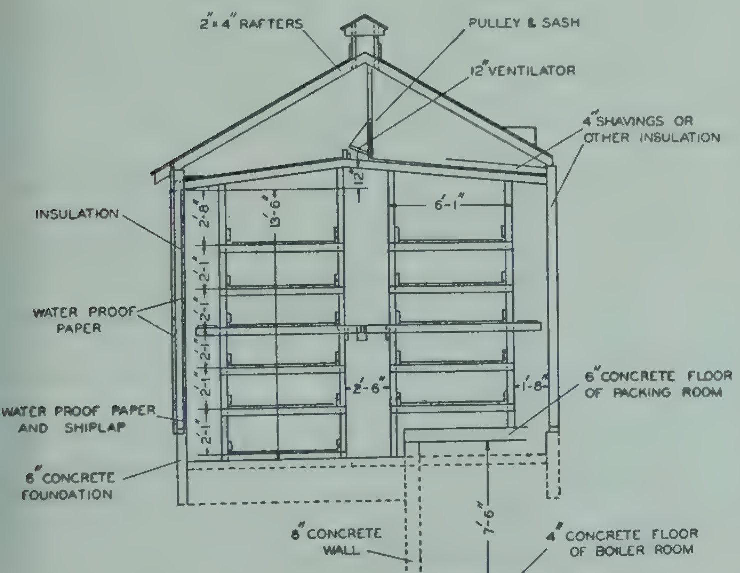

Fig. 2. Section of Conditioned Mushroom House.

Mushroom Houses

Commercial mushroom culture is more nearly a controlled industrial process than the growing of virtually any other agricultural crop. Mushrooms are grown indoors throughout their entire life cycle.

The cultural methods may be briefly summarized as follows: Horse manure is assembled out-of-doors in heaps, carefully mixed, aerated and moistened at weekly intervals for about a month to obtain a favorable partial decomposition or "composting" of the manure; the resulting compost is then brought into the house and made up into shelf beds about 5 in. deep; it is allowed to generate heat in these beds for several days; following this "sweating out" period the house is cooled down to allow for the planting of the propagative material called spawn. After the spawn has grown or "run" in the bed for about two weeks, the beds are "cased" over with an inch covering of soil; a few weeks later the mushrooms begin to appear and the beds continue production for two or three months.

From the viewpoint of air conditioning there are three distinct periods in this process requiring wholly different atmospheric conditions in the mushroom house.

1. The first period follows immediately after the beds are filled, and is called the sweating out period. This term is quite descriptive since during this period the manure in the beds attains a high temperature of 120 to 140 F, and as a consequence loses considerable moisture.

2. The second period when the spawn is running in the beds, requires a moderate temperature, 60 to to 75 F, with a nearly saturated humidity.

3. The third period is the growing period when the

mushrooms are developing on the beds, a time requiring low temperatures, 48 to 60 F, and a moderate humidity. This is the period when refrigeration is sometimes necessary.

Commercial mushroom production is usually carried on within a range of temperature between 45 and 65 F. The rate of growth increases with temperature so that, for example, the white variety grows from a tiny button $\frac{1}{16}$-inch in diameter to a full grown mushroom in 22 days at 50 F, 10 days at 60 F, and 6 days at 70 F. At lower temperatures the mushrooms are firmer and less likely to be diseased or attacked by insects. For this reason, growers prefer to take off their crops at temperatures between 48 and 55 F unless they are concerned with growing two or more crops in one season. In that case 55 to 65 F is the usual range. The yield of mushrooms obtained in a single crop is considered to be slightly higher at the lower temperatures. Refrigeration is usually necessary to produce these desired conditions in the summer time. Heat emission from the beds is calculated at 4 Btu per sq ft of growing surface.

As a rule mushrooms are grown in a relative humidity between 70 and 85 percent. The chief objection to high humidity in cultural practice is the tendency under these conditions for mushrooms to be blemished by parasitic spot diseases.

Pharmaceuticals

Air conditioning is required in pharmaceutical plants to maintain quality and purity, and to permit manufacture throughout the year.[6,7] The removal of air-borne bacteria and dirt is an important factor as well as the control of temperature and humidity.

Colloids absorb moisture on their surface and become sticky, or give up this moisture to the hygroscopic crystals which they contain; crystals dissolve in the water solvent and lose their original state. This is due not only to temperature, but also to relative humidity, and a condition of about 70 F or less and 30 to 50 percent rh is needed, requiring refrigeration.

Cough drop covering is carried on in an air conditioned room. If conditions are not controlled, the drops will stick togethe[r]. Sugar dust will tend to collect on stick[y] surfaces unless air is clean and dried. Con[-]ditions of 80 F and 40 percent rh hav[e] been reported.[8]

Effervescent tablets can be molded onl[y] three months in the year without air cond[i]tioning, which makes possible regula[r] schedules. Conditions desired are 90 F an[d] 15 percent rh.

Gelatine capsules require a dry air t[o] keep in workable form; the air should n[ot] have more than .25 grains per cu ft. Var[i]ous kinds of gelatine require different tem[-]peratures, and machines molding big cap[-]sules also take lower temperatures tha[n] those molding small ones. Thickness of th[e] capsule wall runs .003 to .006 inches. Re[-]frigeration is used to cool the molding pin[s] in automatic machines.

Glandular products and other extract[s] tend to lose their therapeutic value abov[e] 83 F. Since they are very expensive, it i[s] desirable to avoid this loss by controllin[g] temperature and humidity. Glandula[r] products are usually very hygroscopic an[d] in some cases tend to lose their therapeuti[c] value if the water content becomes to[o] high. These products are handled in al[l] stages of manufacture and packing i[n] closely controlled air conditioned room[s] with a temperature of 80 F and relativ[e] humidities from 5 to 10 percent.

Hypodermic tablets are handled in ai[r] conditioned rooms in pharmaceutical plants, to provide comfortable temperatures fo[r] workers with gas masks. The relative humidity should preferably be about 30 percent.

Penicillin and penicillin tablets, etc., one of the newer and major achievements of medicine, is dependent to a large degree on air conditioning and refrigeration. Industry has adopted very rigid moisture specifications and since penicillin is hygroscopic, air conditioning is essential. During the incubation process, temperatures are held within 0.5 F and temperatures and humidities are rigidly controlled during all manufacturing phases.[9,10,11] Air conditioning of all areas where sterile operations are performed is almost without exception a procedure in the industry.

Pills are made in air conditioned rooms to control the quality of coating applied.

The process is one of pouring syrup into a tumbling mass of pills, a process which formerly could not be carried on during humid weather.

Crystals of sugar form on the pill as the water in the solution evaporates. A proper quality of coating is only accomplished when the rate of cooling and the rate of evaporation are regulated by supplying air at the correct dry and wet bulb temperatures.

Rats sold by medicinal houses are stored at room temperature with a humidity of about 50 percent, all conditions being very carefully controlled. A complete refrigeration and conditioning plant and a separate heating plant have been described.[6] The heat load of 150 pounds of rats was taken as equal to the heat given off by one man.

Suture products or animal products used in closing surgical incisions are packed in air conditioned rooms.

Zinc stearate, the white powder used for a dusting powder, is a precipitate from the reaction of stearic acid and sodium carbonate. It must be dried before being ground into powder. In drying, low-velocity air currents are used to decrease the time required. A relative humidity of less than 35 percent is required.[8]

Sensitized Photographic Products*

The manufacture, use, and storage of sensitized photographic products was one of the first and continues to be one of the largest users of refrigeration for air conditioning and temperature control. For instance, at the sensitized goods manufacturing plant of a large photographic concern there is today an available capacity of 24,000 tons of refrigeration. In manufacturing, the temperature of the air must be very precisely regulated, and in many of the manufacturing operations, since scrupulous cleanliness is essential, clean air is necessary.

Manufacture

Sensitized photographic film consists of a transparent flexible support called the "base," upon which is coated a gelatin emulsion containing salts of silver. To form a film base of the required uniformity requires very careful control of temperature, moisture content, and solvent vapor concentrations in the coating machine. The coating wheel must be maintained at the correct temperature to facilitate the proper evaporation of the solvent and to obtain the proper casting of the base. Air in the drying and curing section of the coating machines must have the proper moisture content, must be at the correct temperature, and must be moved at a rate such that the concentration of volatile solvents, removed from the film base, does not exceed a dangerous level of saturation. The film base must be stored in properly conditioned rooms, so that the mechanical characteristics of the material remain constant during subsequent operations.

In the preparation of the sensitive photographic emulsion, gelatin and one or more salts of the alkali halides are dissolved in water and then silver nitrate and other chemicals are added to this solution at a definite temperature. Some of the desired characteristics of finished photographic emulsions are obtained by the temperature of the initial precipitation, and by the temperature and length of time the emulsion is allowed to "digest" subsequent to precipitation.

The emulsion is coated on the film support in a liquid state after which it must be gelled or solidified as quickly as possible. Following this, the excess moisture is removed from the emulsion. The emulsion, held accurately at the proper temperature in a liquid state, is coated onto the film base and is passed directly into a chilling chamber where the gelatin is set. From the chilling chamber, the emulsion coated film goes into a drying alley where it hangs in loops from rods. Temperature, humidity, air purity, and time of drying are controlled with great care to insure a high quality product. As soon as the film has assumed the correct moisture content, it is wound in rolls and subsequently slit and cut into various sizes for packing.

Storage of Raw Photographic Materials

Virtually all photosensitive materials deteriorate with age, but the rate of deterioration is dependent to a large extent upon

* This section by R. G. Tarkington, Technical Staff Assistant to the Director of Research, Eastman Kodak Co., Rochester, N.Y.

the storage conditions. The deterioration of photosensitive material involves a loss in sensitivity, or a loss in contrast, or a growth in fog level, or all three. In the case of color films of the modern three-layer subtractive type, one color sensitive layer may lose speed at a different rate than another, under adverse conditions, and thus upset the color balance of the material. The rate of deterioration is increased by both high temperature and high humidity, while, in general, it is decreased by lower temperature and humidity. Photographic film is packaged by the manufacturer in equilibrium with air at a relative humidity between 40–60 percent, depending on the particular type of film. The relative humidity used while packaging is somewhere within this range. The relative humidity chosen depends on the particular product being packaged and is held to approximately 2 percent.

If possible, film should be stored where the relative humidity of the storage chamber can be kept between 40 and 60 percent, preferably at 40 percent. A moderate temperature with low relative humidity, that is 60 F with 40 percent relative humidity, is better than a lower temperature with high relative humidity, that is 40 F with 80 percent relative humidity.

In general, it is desirable that black-and-white and color films be stored at least below 70 F for a storage period up to two months; below 60 F for a storage period up to 6 months; below 50 F for a storage period up to 12 months. Some sensitized materials may require lower temperatures even for short storage periods, and may warrant special conditions. For specific recommendations, the manufacturer should be consulted. There is no harm in using lower temperatures than those recommended. When the film is to be used, it must be allowed to warm up above the dew point of the air before the can is unsealed. Otherwise, moisture condensation may occur which produces spots on the film.

Processing

The density obtained in a developed image on photographic film depends on the nature of the emulsion, the exposure it has received, and the degree of development. With any particular emulsion, the degree of development depends on the time of development, the temperature of the developer, the degree of agitation of the developer, and the activity of the developer. The effect of temperature on the rate of development is an increase in the rate of development as the temperature rises. When the developer temperature is low, the reaction is slow and vice versa. Within certain limits, these changes in the rate of development can be compensated for by increasing or decreasing the development time. Once a temperature for development is determined for many applications, it should be maintained within approximately $\pm\frac{1}{2}$ F for black-and-white film. In some applications the temperature tolerance can vary from this general figure.

In the development of color film, composed of three emulsions, changes in the temperature of the developer cannot readily be compensated for by changes in development time. Changes in the temperature of the developer may change the development characteristics of the three emulsions in a different manner and upset the color balance, in addition to changing contrast, speed, and fog. Color film, such as Kodak Ektachrome film, therefore, is developed at a recommended temperature of 68 F $\pm\frac{1}{2}$ F. The remaining steps of the development process are not as critical to changes in temperature of the processing solutions.

While the temperature of developers and other solutions must be kept sufficiently low to avoid damage to the emulsion, it should not be so low as to decrease too much the chemical activity of the baths.

After processing, the film is wet and must be dried as quickly and economically as possible. Drying is accomplished by the application of air, hot air, radiant heat, conditioned air, or a combination of these.

Printing Photographic Materials

Most processed film is an intermediate product and is used in making duplicates or prints. No definite conditions of temperature and humidity are required in the printing operation in a large number of instances. It is desirable, however, to keep dust and dirt to a minimum. The use o

ers and if possible conditioned air is advantageous in this operation.

In printing motion pictures, the negative m and raw positive film are passed connuously together through the printer, d registration depends upon the printer sign and the perforations in the two ms. Conditioned, clean air is, therefore, sential in this application as the proper mperature and humidity is necessary in m handling rooms to prevent loss of regration due to differential film shrinkage. addition, it is desirable to maintain the oper humidity to help prevent static arks on the film, as static electricity can sily be generated during this printing peration. Elimination of the static charge so helps keep the film clean. A static arge usually attracts dirt and lint. It is ven more necessary to provide for proper mperature and humidity in printing color otion pictures where two or three images, om as many separate films, must be suprimposed in register onto one film.

Another field of photographic printing here air conditioning is helpful is in the raphic arts. Many operations in preparing he final printing plates for mechanical rinting, and particularly in color printing, equire registration of images which are on ifferent pieces of film or other material. ir conditioning reduces the difficulty in egistration, decreases dirt, minimizes curl, nd makes the material easier to handle.

Storage of Processed Film

The storage of developed film differs rom the storage of the raw stock. The maerial is no longer photosensitive, it is seldom sealed against moisture, and much onger storage periods are generally involved. The conditions to be employed lepend on the value of the records, the ength of time they are to be stored, and whether they are on nitrate or safety base ilm.

Relative humidity is much more imporant than temperature in the storage of processed film. High humidities are paricularly hazardous because of the danger of damage from mold, sticking, etc. A storage relative humidity of 60 percent is the maximum which should be permitted under any circumstances regardless of temperature. Relative humidites below 25 percent should also be avoided because of increased film curl, and the tendency of film to become somewhat brittle under such conditions. Temperatures above normal room temperature should be avoided in storing developed film because of the greater shrinkage which will result. Reduced temperatures are unnecessary for the storage of processed safety film, but are desirable in the case of nitrate film to retard chemical decomposition.

Nitrate films should be stored in unsealed cans, in fireproof vaults constructed and equipped in accordance with the recommendations of the National Fire Protection Association. The storage space should be air conditioned at 50 F or below, and between 25 and 60 percent rh, preferably 40 to 50 percent rh.[13,14] If storage for more than a few years is anticipated, it is recommended that all nitrate films be copied on safety base film and the originals destroyed to eliminate the fire hazard.

Storage of developed safety base films is much simpler, and approved storage vaults are much less expensive to construct. Nitrate films must never be stored in a safety film vault. A temperature of 60 to 80 F and a relative humidity of 25 to 60 percent, preferably 40 to 50 percent, is satisfactory for the storage of safety film.

The long term preservation of valuable film records is an archival problem and requires special precautions. Only safety base films may be used for this purpose. The storage vault should be located and constructed as a six-hour fire resistive vault and protected against accidental water damage. Well controlled air conditioning at 60 to 80 F, preferably 70 F, and 40 to 50 percent rh is more important than in the case of short term storage. The air should be filtered to remove dirt, and, in contaminated areas, cleansed of acidic gases. More detailed information on archival storage is available.[12,13,14,15]

Powder

Powder for explosive propellant charge in guns and projectiles requires control of both temperature and humidity during the loading process. Powder is hygroscopic, and its moisture content determines the

rate at which it will burn. Variations in the burning rate cause inconsistent performance of the guns or projectiles when they are used in actual combat. It is also important to maintain the rh at a uniform level sufficiently high to minimize the danger from explosion of static discharges of electricity. The temperature and humidity conditions to be maintained vary somewhat and are generally set after consultation with the manufacturer of the powder.

Black powder for artillery primers must be dried so that the moisture content is below 1 percent, that uniform burning of the powder will result. In powder train type of fuses, the relative humidity of the powder is such that the moisture content of the powder by weight can be controlled to within 0.1 percent.[21] It is important that room humidity remain constant so that the burning time of fuses will be accurate to within a fraction of a second.

Plywood

Either cold or hot pressing is employed in producing plywood. Where cold pressing is used, the air is maintained at 90 F and relative humidity 15–25 percent.[5] For hot pressing with resin film, the air is also held at 90 F but the relative humidity is increased to 60 percent.

Silk

In the Japanese silk industry, production is evened out during the year by holding eggs in cold storage, which may be done successfully at 32 to 40 F with a high humidity. More than half of all the silkworms are hatched from eggs that would normally hatch in the spring. Raw cocoons are also stored at low temperatures, 26 F being reported.

Textile Processing Industries*

Industrial air conditioning has always been necessary for textile processing whether the humidity conditions that were necessary were obtained by atomization of water, by more modern central station spray type units, or even with unitary equipment of ingenious design to discharge supersaturated air within the space to be conditioned.

* This section prepared by A. C. Buensod, President, Buensod-Stacey Co., New York, N.Y.

In the past three or four years, the use refrigeration in connection with the a handling equipment for humidifying in th textile processing has become more wide used. One of the main reasons that refri eration has become appreciably importa is that the synthetic or man-made fibe have taken a larger part in textile proces ing and, in general, the relative humiditi permissible in weaving are lower than tho that are customarily used for cotton fiber

Without refrigeration as a means of coo ing, the maintenance of lower humidi means higher dry bulb temperatures in th room in summer. Maintenance of unifor winter and summer conditions, suitable f fibers that are processed, is of the utmo importance in order that higher produ tion, with higher quality, may be obtaine

The central station evaporative cooli system has been in wide use for many year In addition to artificial cooling by means chilled water, it made possible maint nance of ideal conditions for each of th processes throughout the year. Most of th systems used of the central station ty were supplemented by atomizers to redu the air handling capacity. With the use chilled water, the air handling equipme could further be reduced in capacity a more of the work done with atomize thereby further justifying the cost of r frigeration.

The use of refrigeration for textile pro essing is usually designed so as to mainta an "effective temperature" of from 78 to F. These conditions are in effect comfort ble for the operators and, in general, pe mit a range of dry and wet bulb temper tures which are correct for the proper o eration of the fibers used in the texti processing.

The use of a complete year-round syste of refrigeration in textile processing is pr dicted for the majority of textile processi industries, especially where synthetic fibe are being used. The cost of operation w be not much higher than the present o erating cost for plain evaporative coolin and such additional cost, if any, will compensated by the uniform results higher production efficiency with high quality.

In the knitting textile processing indu

y, it has been almost a universal standard utilize complete air conditioning, including refrigeration, to maintain ideal conditions for the knitting frames, thereby insuring production and high quality. Uniform temperature regulation is of more importance than the maintenance of humidity conditions. For this reason, a humidity 50 percent is usually advised and no supplementary atomization is used.

Tobacco

Another example of what may be done y industrial air conditioning in the control of color, texture, and flavor is found in the case of cigars, cigarettes and other tobacco products. Air conditioning is necessary from the very time the tobacco is harvested and brought in from the fields. It immediately stored in buildings with very high relative humidities and temperatures (over 90 F) in order to hasten the fermentation which ages the tobacco and improves its quality. In preparation for stripping, the tobacco undergoes what is known as a softening operation, being automatically heated, moistened, and then cooled. It is more easily handled when it is moistened enough to be soft and pliable, but it should not be too wet or it will mold and lose its flavor. Temperatures and humidities recommended for four operations in the tobacco industry are as follows:

Operation	Temp, F	RH, %
Cigar and cigarette making	70–75	55–65
Softening	90	85–88
Stemming or stripping	75–85	70–75
Packing and shipping	74	65

An interesting example of the economic value of air conditioning in the tobacco industry is found in one factory in the East, where Cuban temperatures and humidities are maintained in the manufacture of high-grade Havana cigars. These are sold at half the price of equivalent imported cigars, with duty charges eliminated.

In the Philadelphia plant of the American Tobacco Company, another large saving from air conditioning has been reported; reduction in lost time, labor turnover, rejections, and increased production have amounted to nearly $30,000 a year, or more than $23,000 over the combined fixed charges on the air conditioning equipment added. Rejections have been reduced from 3 – 4 percent to 0.5 – 1 percent.

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If you searched this chapter for something which was not found in it, please let the editors know.

74. PRECISION MANUFACTURING AND WORK EFFICIENCY

As noted in the foregoing introductory chapter, precision manufacture requires the making of parts with very small variations of size, and the assembly of such parts regardless of when or where they were made. Air conditioning for precision manufacture thus requires great constancy of the given conditions of temperatures, humidity and cleanliness. Typical applications are to industries making the following products: Watches, gages, instruments, meters, radio and radar parts, gear-cutting machines, aviation engines, printing machinery, optical goods, photographic developing equipment and laboratory testing apparatus.

Another class of industrial situations concerns the efficiency of personnel. Air conditioning lays broad claims to improvement of working conditions in factories, as it does in offices, operating rooms, drafting rooms, studios and the like. In some cases air conditioning is needed both for precision and work efficiency. Some of the following industries use air conditioning for one reason, some for both.

Machine Shops

Engineers and designers have stepped up the demands of manufacture so that precision work is more necessary than ever before, and uniformity in such work demands uniform **temperature** and **humidity** conditions. Some precision parts have been rejected when made on machine tools exposed to the sun at certain times of the day. Some parts cannot be made to the accuracy now demanded if the atmospheric conditions are not constant during all of several days of manufacture. An example is the large gears which are used for marine propulsion, some of which take 17 days for hobbing. Parts may be assembled into machines at various assembly plants distant from the plant which manufactured them. Parts may be used for replacement in every corner of the world, and they must be interchangeable. Air conditioning for maintaining constant temperature, humidity and cleanliness of air has been the answer to these many problems of precision manufacture in machine shops.

Gage Rooms

Precision manufacture depends also upon **gages.** The primary gages are laboratory instruments only, and the art of making these has been developed to a high state of perfection. Gages are sensitive to changes in conditions of temperature, humidity and cleanliness during their manufacture and use.

Primary gages must be maintained under constant conditions for use as standards against which secondary gages are periodically checked. Secondary gages have to be manufactured under the same constant conditions, but, as they are used in various places where manufacturing processes are utilized, they are accurate only to the degree that constant conditions are maintained in the manufacturing processes. Secondary gages should be stored in air conditioned rooms.

Experienced gage testers say that when the temperature of the gage room varies more than 1 F they can detect it in the gages. Therefore, tolerances are generally held to ±1 F. Relative humidity is usu-

Walter C. Goodwin, Author, Chapter 74. Born in Pittsburgh, Pa. Educated at Pennsylvania State College, BS, 1915. Formerly with the Eng. School and Design Class and later as Section Engr.—Control; Liaison Engineer in Europe; Engrg. Dept. Mgr.; Division Engr., Air Conditioning; Application Engineer, Air Conditioning; Manager, Precipitron Dept., Westinghouse Electric Corporation.

Author of articles in *Heating, Piping and Air Cond.*: AIEE Journal; *Refrig. Eng.*

Member of AIEE, Secretary and chairman, Pittsburgh Section; Member, Amer. Standards Assn., B-9 Committee.

At present, Product Manager, Heat Transfer Products, Sturtevant Division, Westinghouse Elec. Corp., Boston, Mass.

ally held within ± 5 percent of a desired point. Because of the danger of destructive condensation on gage surfaces, excessively high relative humidity must be avoided.

Instrument Assembly

Instruments are judged by their accuracy, and the parts from which they are made demand extreme accuracies. Many parts have to be nearly frictionless, making polished surfaces important.

The temperatures usually employed in this field are between 75 and 80 F with ± 1 F tolerance. The relative humidity conditions generally maintained are between 45 and 50 percent. Cleaning of the air is generally obtained by both impingement and electrostatic type air filters. Not only must the parts be accurate and clean, but the workers' hands must not impart moisture or dirt to the accurate and delicate parts and surfaces such as jewel bearings and stems which ride in these bearings. Air conditioning has been a big factor in the success of modern accurate instruments.

Drafting Rooms

Drafting rooms are air conditioned for both precision manufacture and work efficiency. In the first place, designs which are pictured on drawings have to be drawn to scale. In many new plants the drawings or reproductions of the drawings are used as templates for the manufacture of working tools or parts, especially in the aircraft industry. Here temperature and humidity control prevent variations in size and distortion in shape. Concerning work efficiency, draftsmen have been proved to turn out more and better work where uniform air conditions are maintained, and where perspiration and dirt are not permitted to affect the drawing. Conditions in drafting rooms are generally kept at normal comfort levels, usually at 80 F and 50 percent rh with normal variations.

Since drafting rooms are often large, open spaces, special attention has to be given to air distribution. Uniform conditions should be obtained over the room whether near the outside walls or far from them. As draftsmen usually lean over their work, special attention has to be given to keeping the space free from drafts on the backs of their necks.

It is generally desirable to keep the temperature of the conditioned air entering the room at a relatively small temperature differential below room temperature by mixing room air with conditioned air either with bypass dampers or aspirating types of air outlet grilles. Air movements at the working height should not exceed 10 to 15 ft per min. If the room is large or has two or three exposures it should be zoned.

Blackout Plants

Wartime blackout plants have generally been one-story buildings extending over large areas. As a result, different methods for air conditioning have been developed. Two general methods have resulted: (1) The conventional method using a central machinery room, or building where a chilled medium and a heating medium have been produced and pumped to many air-handling units, each of which would handle an individual area or zone; (2) the zone-unit system. Cooling machinery, suitably sized for each zone, is located at that zone. The heating equipment may be located at the zone or at a central location. The zone unit system saves one heat exchange as the cooling can generally be done by the direct method. Other advantages are the saving in first and operating cost of such auxiliary equipment as pumps and insulated piping. Both of these methods have been used extensively in these large-area, single-floor plants. The air-handling units for each zone are generally located in roof trusses or in penthouses on the roof.

These air conditioned factories proved themselves during the war and also since the war for different purposes. The experience confirmed the basis on which they were originally designed and especially the air conditioning. They definitely showed (1) better and more uniform quality of product, (2) increase in production due to conservation of workers health and energy and (3) reduction of accidents due to fatigue.

Use of these plants has given history of operating costs and together with known installation costs the yearly costs are now available.

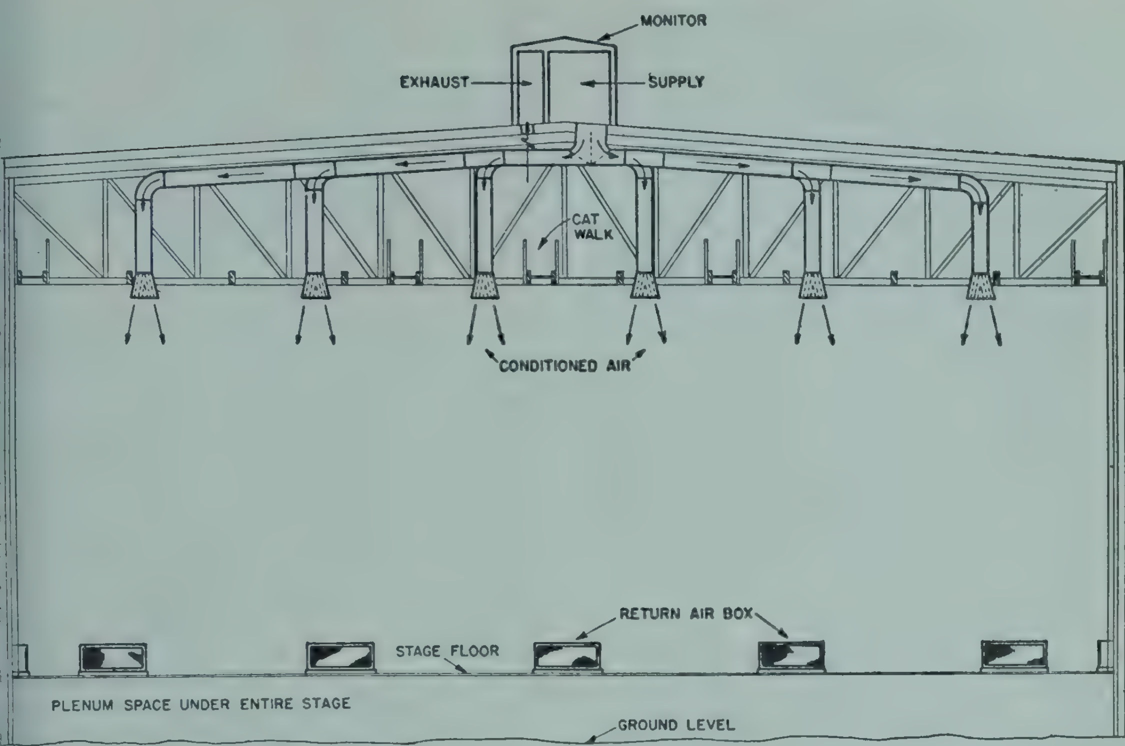

Fig. 1. Section of Movie Sound Studio Showing Ducts for Conditioned Air.

Mining

The heat and humidity encountered in nines may cause higher body temperatures and acceleration of pulse, injurious to productiveness. Dust from mining processes endangers health of workmen; gases, sometimes poisonous or explosive, must be removed. It has been found economical and desirable to air condition gold mines by machinery located at the outdoor level or at lower levels. This permits working of lower levels of mining.

The Rand Mine, in South Africa, uses an air circulation of 400,000 cfm and 7,500 gal of water per min circulated to a spray pond. Fans lead to a duct system which enters the vertical shaft 100 ft below the surface. The refrigeration system in this mine has three 750-ton centrifugal machines and a dehumidifier 50 ft×16 ft wide. The average depth of a gold mine in the vicinity is 4,000 ft.

It is believed that mining can be carried on as far below the surface as 12,000 ft, if air conditioning can be provided economically. This means an increase in revenue in the South African mines of $100,000,000 in the value of gold available for every increase of 200 ft in depth. If the depth goes 6,000 ft more, three billion dollars worth of gold may become available.

Wet bulb temperature is the guide to mine conditions; a wet bulb of 92 F with a velocity of 50 ft per min is the minimum requirement. In the case of a mine producing 150,000 tons monthly at 6,000 ft, the heat load appears to be 70,000,000 Btu per hr.

Three methods of cooling are possible: (1) Surface refrigeration consisting of a plant to cool air and force it down from the top; (2) underground refrigeration plant (for example, one installation 6,400 ft below the surface, cools 8,000 tons of air per day to a maximum temperature of 83 F); (3) compressed air operation of machinery in the mine.

Air conditioning to temperatures below normal by means of well water and refrigeration is practiced in certain coal mines in this country, where trouble is experienced in warm weather with falling roofs. There

are various theories as to why roofs are more likely to fall in warm weather, such as (1) the effect of temperature variation on expansion of rocks, (2) weakening of roof material due to wetting, and (3) unknown chemical action. A single set of fans with an air-washer type of cooler was used in the first of the coal mines devoting attention to this problem in 1931. Later a mine in Indiana set up a dehumidifier arrangement by installing sprays in a brick-lined chamber at the foot of the main vertical shaft. Air was blown by motor-driven fans through a course in the horizontal shafts. Water for cooling purposes was available from a flooded, unused portion of the mine, and, after use, was pumped from the spray to another abandoned portion. Temperatures of 50 F were reported in both cases.

Moving Picture Studios and Film Making

Modern movie stages are large, insulated buildings; the soundproofing makes other treatment necessary for satisfactory occupancy. **Lighting,** the greatest contributor of heat within, is variable as to amount and duration, and must be correctly controlled. Size and number of sets are variable and create individual problems, and both the number and types of persons on a sound stage play their parts in relation to air conditioning.

High-salaried personnel, often in costume, demand comfort while working. Less time is lost in make-up retouching and less delay brought about by perspiration-dampened costumes, when sets are properly cooled.

An air conditioning system should have the ability to heat, cool, ventilate, and clean. Stages are generally maintained at 75 F and 50 percent rh, with temperature settings above and below, at the option of the occupants. Floor distribution of air has the advantage of more economical removal of rising heat but the disadvantage of placing set construction and personnel too near the source of cooling. Overhead distribution has the advantage of better temperature distribution but is less economical in the removal of rising heat from lights (**Fig. 1**).

Film making demands precision manufacture and air conditionihg is found necessary. The materials are hydroscopic, there must be an absence of dust and the product must be accurately slit and perforated. This application is treated more fully under "Sensitized Photographic Products" in Chap. 73, Storage and Processes.

Optical Goods

Modern optical instruments such as bomb sights, range finders, telescopes, binoculars, cameras, etc., require extreme care in manufacture in order to obtain optical accuracy. The fundamental part of such devices is the lens. The lens must be ground and polished. In this process, the accuracy required is such as to make air conditioning necessary. The air must be dust-free and temperature constant. The wax in which the lenses are imbedded must be firm. The polishing rooms must be free from air-borne dust and impurities. When the component lenses are assembled into groups, they must be free of dirt and perspiration marks, and the cement must be maintained under constant conditions.

The conditions generally maintained are similar to those in other manufacturing processes, such as 80 F dry bulb temperature and 50 percent rh. To get the desired cleanliness of air, combinations of impingement and electrostatic air cleaners are often used.

Abrasives

In the precision manufacture of abrasive materials such as sand paper and abrasive wheels, controlled conditions of temperature and humidity contribute much to manufacturing efficiency and quality. Precision depends in many cases on grinding operations, and accurate grinding calls for a high-grade grinding wheel. The quality of the grinding wheel depends in part upon the air conditions under which it is manufactured and used.

Abrasive wheels are normally bonded with materials such as bakelite, clay, hard rubber or sodium silicate; in some cases hygroscopic. Abrasive grains are added when bakelite is in liquid form; the room temperature is controlled to insure constant consistency. When the bonding ma-

terial is of ceramic clay, relative humidity control prevents lumping of the clay. Unless used (and stored) in an atmosphere free of excessive humidity, deterioration of the wheel will take place. The usual air conditions for the manufacture of abrasives are 78 F dry bulb temperature and 50 percent rh.

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If you searched this chapter for something which was not found in it, please let the editors know.

75. LABORATORIES AND TESTING

ENGINE, SUPERCHARGER AND INTERCOOLER TESTING

FROM the engineer's viewpoint an engine, supercharger, and intercooler test laboratory consists of an enclosure just large enough to house the equipment to be tested and to permit the test attendants to move about. Such a test room and connecting equipment are shown in **Fig. 1.** In this system, induction air is introduced into the induction cooling system, passed through the two-stage supercharger, the parallel intercoolers, carburetor, and engine, and then discharged to the vacuum pump as exhaust gas. The intercooler air is recirculated, providing cooling for the intercoolers and test chamber.

The types of engines to be tested vary from simple, single-cylinder, vertical, two or four-cycle engines to the more complicated multi-cylinder in-line or radial airplane engines. Fig. 1 shows a radial airplane engine and test stand of the type which will be considered here.

Superchargers are used almost entirely on airplane engines. Their function is to take rarefied air at high altitudes and compress it to roughly 25 lb per sq in. for injection into the carburetor, thereby permitting the airplane engine to deliver rated horsepower under the rare-air condition. Superchargers may be either gear-driven from the engine or exhaust-gas driven from the engine. Either type may be single or multi-stage, two stages of compression generally being used in the multi-stage unit.

Intercoolers are generally two parallel or cross layers of heat transfer surface. The discharge air from the supercharger passes through one layer, and the cooling air circulates through the other, acting to remove the heat of compression added to the air in the supercharger.

Tests performed are load tests at ambient conditions, at sea level, or tests under abnormal weather. Load tests at ambient conditions are very common and are generally run in an open factory building without air conditioning or refrigeration. Starting, running, load, and life tests at abnormal weather conditions are necessary to assure the manufacturer a product which will perform as expected when subjected to salt air, wind, dust, and sand storms, high and low altitudes, temperatures, and humidities. This type of test requires considerable cooling, heating, filtering, humidification, and in some cases, production of salt air, or dust storm atmospheres.

The most common conditions required and generally the most difficult to produce are low temperature, high altitude, and low humidity simulating conditions encountered by an airplane engine, supercharger, and intercooler in flight.

The air conditioning and refrigeration engineer's problem is to design the induction and intercooler air cooling systems, and he is also called upon to specify the amount, type, and location of the room insulation.

Design Considerations

The engineer writing the specifications on which the refrigeration man is to bid, will generally give the length, width, and ceiling height of the clear space required for the equipment to be tested, and may

Coy W. Brown, Author Chapter 75. Born 1/17/06 in Bells, Texas. Educated at Oregon State College. BS, 1930. Formerly, Test Engineer, General Electric Co., 1930–32; Field Engineer, 1932–39; G. E. Co. Special Assignment, Walt Disney Studios, 1939–40; Field Engineer, General Electric Co., 1940–44; Engineer, Application Engrg. Div., Air Conditioning Dept., General Electric Co., 1944–49.

Author Chapter 70, 1946 Applications Volume, ASRE Data Books. Author of a number of articles on air conditioning published in Yearbook for Buyers Guide of the Independent Film Journal; *Heating and Ventilating*, *Box Office Magazine*.

Member, Amer. Soc. of Heat. & Vent. Engrs.

At present, Engineer, Service Data and Instruction Manuals, Air Cond. Dept., General Electric Co., Bloomfield, N. J.

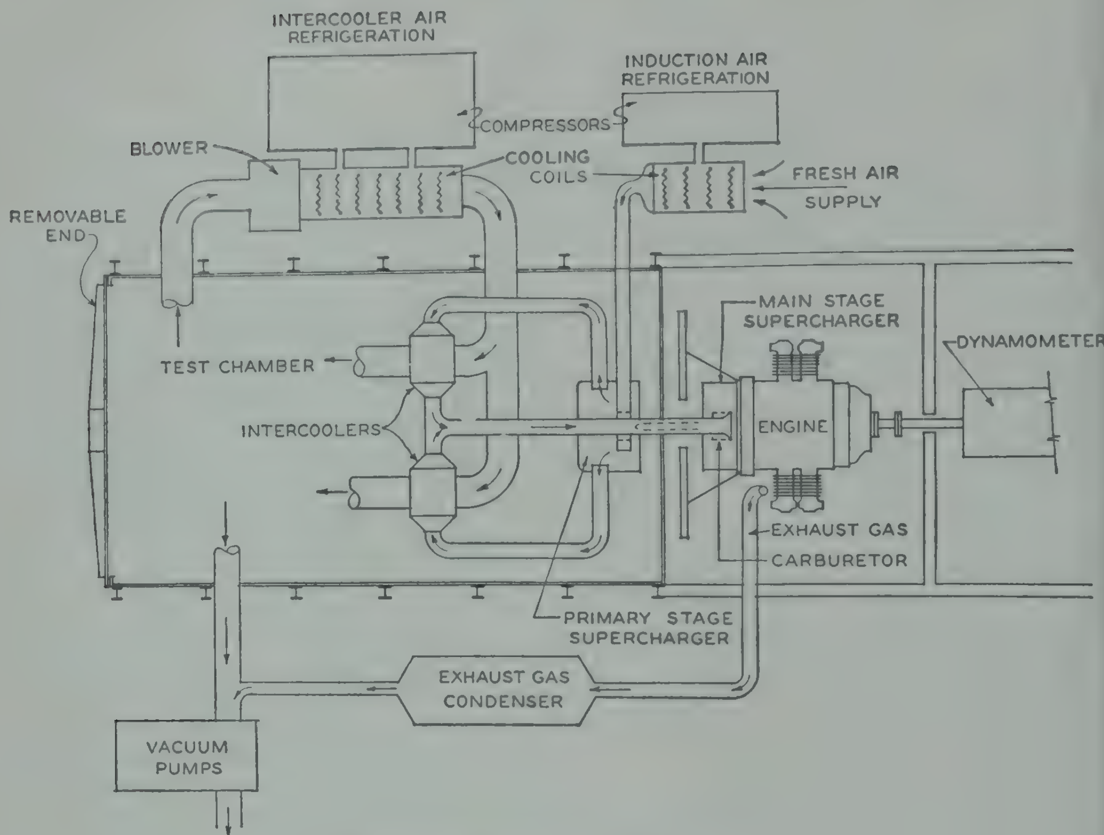

Fig. 1. Induction System for Test Room.

permit increase in the room dimensions to allow for air conditioning apparatus. It is generally desirable to locate the equipment outside the test space so that the room dimensions remain as specified.

The specification engineer will also give the room wall construction, ambient conditions surrounding the room, air flow in lb per min entering the supercharger, and the intercooler, the temperature, pressure, and humidity required at critical points in the system.

A typical set of conditions required is shown in **Fig. 2.**

For quick pull-down, from 10 min to 5 hr, test room **insulation** should be light in weight, of low specific heat, of low conductance and should be impervious to moisture. The insulation should be inside any heavy steel walls, if possible, to prevent the necessity of removing the stored heat from the steel during pull-down. The weight of metal supports or engine bed plates in the room should be kept to a minimum, for the same reason. It is also desirable to eliminate heavy metal liners in the room. A 20-gage sheet metal liner will almost follow the room temperature down during pull-down.

For slow pull-down, 12 hr or longer, the effect of bed plates, liners, and insulation inside or outside the room should be considered but may not be important. The pull-down load here becomes less than steady-state load, and capacities can be based on the latter.

Altitude, Pressure, and Temperature

Room temperatures and humidities required will vary from approximately 150 F dry bulb down to −110 F. The relative humidity required will approach saturation, approximately 95 percent, but usually not at temperatures in excess of 90 to 95 F.

Room pressures required will vary from atmospheric to that equivalent to ap-

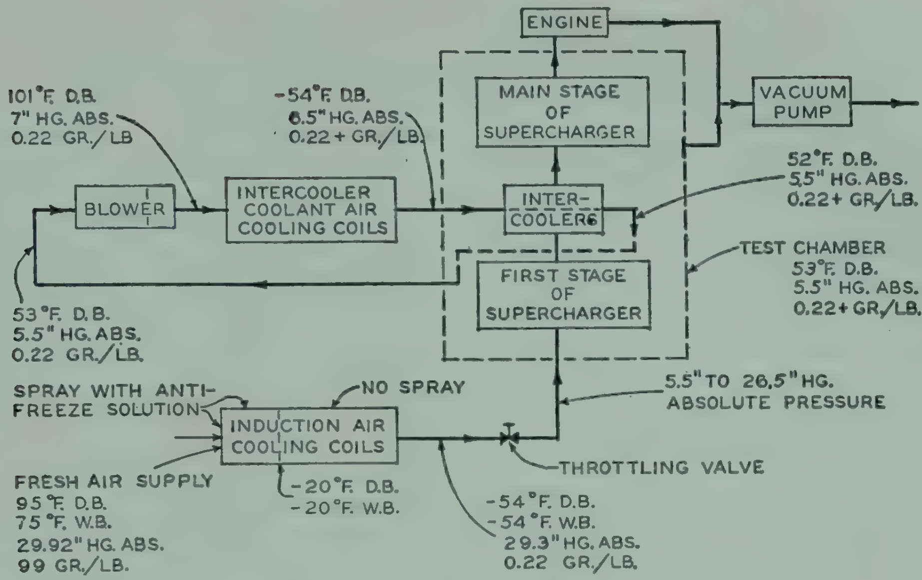

Fig. 2. Typical Air Conditions for Induction System Test Chamber.

proximately 40,000 ft of altitude. **Table 1** gives standard atmospheric pressures and air densities for the various steps of altitude. Also opposite the altitude figures are probable design temperatures that may be specified.

It should be noted that the temperature levels off at −67 F at 35,000 ft. Readings taken in the last few years show much lower minimum temperatures than this. Low readings vary from −75 to −120 F at 32,000 to 55,000 ft. In line with these lower temperature readings, recent engine, supercharger, and intercooler test rooms have called for room ambient temperatures as low as −110 F at altitudes varying from 35,000 to 55,000 ft.

In designing a system of this type, particularly in selecting cooling coils and blowers, the air engineer is called upon to convert the actual rare air condition back to standard air. This conversion permits considerable simplification of equipment selection calculations. **Standard air** is air at a temperature of 68 F dry bulb at standard barometric pressure of 29.92 in. of mercury, which contains 0.0725 lb of moisture per lb of dry air. Standard air weighs 0.07488 lb per cu ft (definition is from ASRE Standard 16-R "Standard Methods of Rating and Testing Air Conditioners.")

Table 1

Altitude, ft	Atmospheric pressure, in. of mercury	Temperature, F
0	29.92	59
5,000	24.8	41
10,000	20.5	23
15,000	16.9	5
20,000	13.8	−12
25,000	11.1	−30
30,000	8.9	−48
35,000	7.0	−67
40,000	5.6	−67
45,000	4.4	−67
50,000	3.5	−67

Coil and Ductwork Pressure Drop

The conventional duct pressure drop charts give pressure drop in in. of water per 100 ft of duct and for standard air. The air engineer will need to calculate the pressure drop for other than standard air. The pressure drop for other than standard air may be determined from the following formula:

$$\text{Pressure drop at actual density} = \text{Standard air pressure drop} \times \frac{\text{Actual air density}}{\text{Standard air density}}$$

The resistance to air flow through coils

is usually given by the manufacturer in inches of water for standard air. The pressure drop at actual density specified may be determined as follows:

Convert actual air flow to standard air flow and and then, from the manufacturer's curve, determine standard air flow pressure drop across the cooling coil. Then adjust the standard air pressure drop to actual pressure drop by the following formula:

$$\text{Actual pressure drop} = \frac{\text{Density of standard air}}{\text{Density of actual air}} \times \text{Pressure drop for standard air.}$$

Fan capacities are given by manufacturers in cu ft of air per min for standard air at various fan speeds and system pressure drops. To apply fans handling air at high or low pressures, high or low temperatures, it will be necessary to make corrections as follows:

Assume a fan is to be selected to circulate 5,000 cu ft per min of -100 F air at 35,000 ft of altitude and 3 in. of water pressure drop. The following steps are to be followed:

1. From Table 1, 35,000 ft of altitude corresponds to 7 in. of mercury absolute pressure.
2. Determine altitude or pressure and temperature correction factor.

$$\text{Correction factor} = \sqrt{\frac{\text{Actual absolute temp}}{\text{Standard air absolute temp}}} \times \sqrt{\frac{\text{Standard absolute press.}}{\text{Actual absolute press.}}}$$

$$= \sqrt{\frac{460-100}{460+70}} \times \sqrt{\frac{29.92}{7}}$$

$$= .824 \times 2.065 = 1.7.$$

3. Correct the air flow in cubic feet of air per minute for effect of temperature and pressure change from standard air temperature and pressure.

$$\text{Corrected cfm} = \frac{\text{Actual cfm}}{\text{Correction factor}} = \frac{5,000}{1.7} = 2,940 \text{ cfm}$$

4. Select a fan from the manufacturer's catalog for the corrected cubic feet of air per minute and the actual static pressure, i.e., 2940 cu ft of air per min and 3 in. water static pressure. Several sizes of blowers will give the desired capacity. Select the one whose speed, size, and outlet velocity is suitable for the application and will give satisfactory noise level and length of life.

For example, choose No. 350E blower rated at 3097 cu ft of air per min at 1121 rpm, 2.47 brake hp and 3 in. of water static pressure.

5. Correct the blower speed, brake horsepower and cubic feet of air per minute obtained in step 4 as follows:

$$\text{Speed} = 1121 \times 1.7 = 1907 \text{ rpm}$$

$$\text{Bhp} = 2.47 \times 1.7 = 4.2 \text{ bhp}$$

$$\text{Actual cfm} = \frac{3097}{2940} \times 5000 = 5225 \text{ cfm}$$

6. Then the complete specification for the blower is No. 350E, 5225 cfm, 1907 rpm, 4.2 bhp.

This blower will circulate 5225 cu ft of air per min of -100 F air at 35,000 ft of altitude with 3 in. water static pressure drop.

Typical **intercooler pressure drop curves** are shown in **Fig. 3.** Pressure drop is shown for both cooling air and the air to the supercharger. In addition to overcoming other resistances of the system, the air engineer will need to select the blower to overcome the intercooler pressure drop in the intercooler air cooling system.

Cooling Coil Performance

As in any low temperature application, the cooling coil capacity is selected by converting actual air flow to standard air flow, and making the coil selection calculations for the standard air flow. When the refrigerant temperatures are below -20 F care should be taken to check the loading per refrigerant circuit, and the circuit exit refrigerant gas velocity should be calculated to make sure that they are not excessive, giving too high pressure drop.

Where defrosting is required, necessitating spraying a brine solution over the coil or periodical shutdown for defrosting, the number of fins should be reduced to not more than 4 or 6 per in. of evaporator tube. Keeping down the number of fins per inch gives a better ratio of refrigerant side to air side surface, and allows room for the

air and defrost solution to pass without excessive air velocity. It also provides room for frost accumulation without causing too high resistance.

Defrosting Methods

Generally, recirculation systems such as the intercooler air system in Fig. 1 do not require defrosting except for tests of more than several days' duration or for tests having poorly sealed test rooms. If, however, the closed circuit test is to be for a long duration, if the test room leaks, and shutdown is not permitted, some means of defrosting must be provided.

If the design temperature is lower than −20 F, two duplicate banks of coils may be provided to permit defrosting one while the other is in operation. If continuous operation is required, and the design temperature is −20 F or above, defrosting can be accomplished continuously with the system in operation by spraying the coil surfaces with a defrosting solution, generally ethylene glycol mixed with water. This solution is then reconcentrated by boiling off the excess water, cooled and returned to be used again.

Where continuous humid makeup air is introduced into the system, as in the induction air system of Fig. 1, continuous defrosting is necessary and must be carried to as low a temperature as permissible without freezing the solution. Using solutions now on the market, defrosting may be accomplished down to about −20 F.

Cooling the air to −20 F removes most of its moisture content, but the remaining moisture may still be a problem for the air engineer. Perhaps it can be removed by spraying the coils which carry the temperature below −20 F with alcohol, using a minimum quantity of alcohol required to form a soft slush with the accumulated water. In the use of alcohol, care should be taken to make sure the slush will not harm the equipment handling the air below −20 F and to make sure that the alcohol vapors do not produce explosive or other dangerous atmospheres.

Specifications generally do not call for humidification below freezing temperature, and, therefore, this problem will not be considered here. The production of **high humidities** above freezing, however, are common. One of the most satisfactory sources of humidity is live steam introduced into the air stream ahead of the

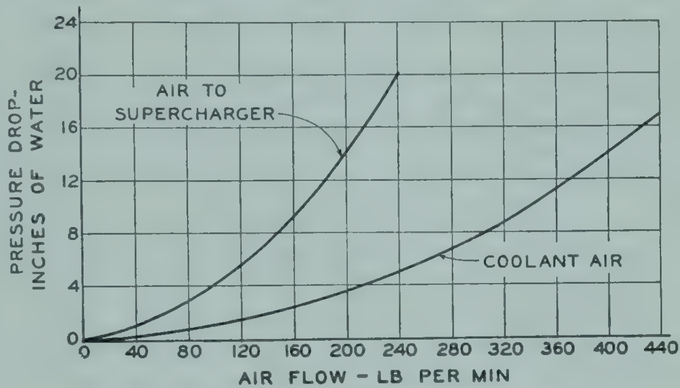

Fig. 3. Typical Intercooler Pressure Drop.

blower through suitable jets in the steam line. In the design of such a steam-jet humidifier care must be taken to place the humidifier over a drain pan and make the steam supply piping as free-draining as possible, to prevent squirting water when the humidifier solenoid opens and to prevent freezing at low temperature.

As an alternate source of humidity, the electric or steam boilers may be used to evaporate water, or many of the standard humidifiers on the market may be applied. Dehumidification is not a very common requirement for this type of job and will not be considered. Where the heating coil may be subjected to low temperature, electric heat for heating or defrosting is preferable, but steam may be used if suitable precautions are taken against freezing.

Condensing Unit Performance

Both reciprocating and centrifugal condensing units are used to provide refrigeration for laboratories and texts. Multi-staging is desirable for the lower temperatures. For example, typical application ranges for reciprocating machines are:

Down to minus 40 F evaporating refrigerant temperature—single stage using Freon-12 or Freon-22 refrigerant.

Minus 40 F down to minus 100 F evaporating

refrigerant temperature using either F-12 or F-22 refrigerant—two stage or two stage cascade.

Minus 100 F to minus 120 F evaporating refrigerant temperature—either two or three stage with Freon-22 refrigerant. Two stage is predominant in this range.

Below minus 120 F refrigerant—two or three stage cascade systems with Freon-12 in the low stage and Freon-12 or 22 in the high stages.

Any systems requiring evaporating refrigerant temperatures below minus 40 F should be attempted only by engineers experienced in this presently special field.

Other Test Methods

An alternate to the test method in Fig. 1 is shown in **Fig. 4.** In Fig. 4, air at atmospheric pressure is compressed to approximately 25 lb per sq in. gage pressure. During compression, the air temperature rises from 90 to about 300 F. The air is then cooled to about 100 F with city or well water cooling coils. It is then cooled to approximately 0 F with refrigerant or brine cooling coils. Leaving the cooling coils at 0 F and 25 lb per sq in. gage pressure, the air is expanded through a turbine which may be a supercharger. During expansion, work is done by the air and an equivalent heat content is removed, reducing the air temperature. The amount of re-expansion and work done by the air turbine may be controlled to give the temperature desired entering equipment on test. For this type of system, the same comments regarding pressure drops, defrost, heating and humidification apply.

In designing an engine, supercharger, or intercooler test room, air conditioning or heating equipment, some precautions should be taken. Some more critical ones are given in the following paragraphs.

The supercharger is essentially a high-speed device and is generally operated at high speed for the first time in the test room. Due to its high speed, the possibility always exists that a bucket may come loose or other mishap occur causing the supercharger to explode. If an explosion occurs, loose parts fly in all directions at high speed. To protect nearby factory workers, the supercharger test-cell walls should be protected with heavy steel plates arranged to stop any such flying particles.

For operation at other than atmospheric pressure, the test room and connecting ductwork walls must be designed to stand the pressure differentials. Also, in calculating the pull-down load, the heat storage of these heavy walls must be considered. To minimize moisture removal, one may

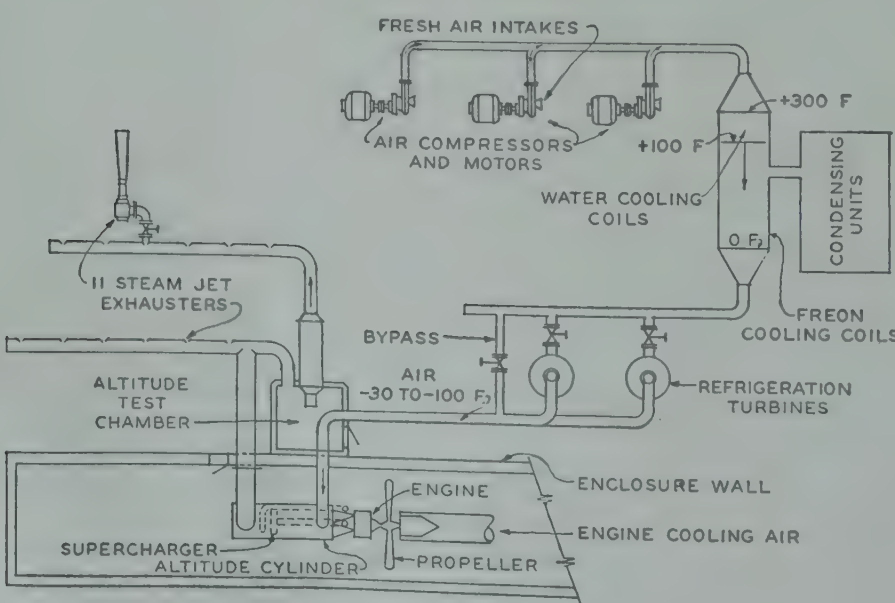

Fig. 4. Compressed Air Supercharger and Test Chamber.

reduce the leaving air temperature as much as possible, with the coils sprayed with defrosting solution, install good eliminators to prevent solution carryover, and make a check to see that the remaining moisture in the air will not cause excessive ice accumulation on succeeding coils or in the refrigeration turbine.

Other Machinery Tests

Accurate inside, outside and depth gages are calibrated at temperatures varying from 68 to 70 F dry bulb, to prevent inaccuracies due to expansion and contraction of the gage metal. When in constant use, they should be stored at the calibrated temperature year around. Relative humidity variations are not important. Considerable variation in relative humidity will not affect the gage accuracy as long as rusting is prevented by maintaining reasonable relative humidity or by an oil film on the gage parts.

Airplane transmitters are now tested under simulated flight conditions. Except for insulation breakdown tests pressure variations are not considered to affect the transmitter performance, but temperature, rate of temperature change and relative humidity do affect their performance.

Typical **radio test cabinets** provide the following conditions: Temperature change from 3.5 F per min maximum to 1.0 F per min minimum, over a range of from 104 F to −4 F; humidity control up to a maximum of 95 percent over the entire temperature range. While subjected to this cycle, the transmitter must not cut out or have wide swings in sending frequency. The temperature and humidity control can be manual or automatic, preferably the former, since a full-time operator is generally required to connect the transmitter and observe its performance.

WIND TUNNELS*

A WIND tunnel is any large tube through which an artificial flow of air is produced by means of a fan or blower, with the object of studying the action of the airstream on aircraft models, component parts, or other aerodynamic bodies. Wind tunnels may be classified according to the following **types**:

Open return. This type resembles a large Venturi tube in which the air is drawn from the outside, accelerated through the nozzle and discharged again from the end of the diffuser.

Single closed return. In this type, the air circulates around a closed circuit. In this way the same air is used over repeatedly and there is no kinetic energy loss. The fans, therefore, only have to overcome the internal tube losses in order to maintain circulation of the air.

Double return. In this type, the air splits at the end of the diffuser and returns through two divided passages. This type results in some saving of space over the single closed type, although the balancing of the return passages to obtain symmetrical, uniform flow is more difficult.

Annular return. Here the air circulates in a complete annular passage. This type furnishes the maximum economy of space, but presents problems of accessibility since the test is completely surrounded by the return air passage.

Types of **test sections** are as follows:

Closed throat. The test section is entirely enclosed, and highest air speeds are obtained with this configuration.

Open throat. The test section is represented by an open jet. While convenient with regard to accessibility, speeds are limited due to the relatively high losses associated with the free jet, and a tendency for organ pipe pulsations to be set up at critical speeds.

Partially closed throat. This configuration with walls partially enclosing the jet represents a compromise between the other two.

The energy ratio is the ratio of the kinetic energy in the jet to the power delivered to the fan. The power which the fan supplies is under conditions of steady flow equal to the sum of the power losses through the tunnel circuit. The losses may be estimated as follows:

* This section by Frank L. Wattendorf, Scientific Consultant, Air Matériel Command, Dayton, O.

Cylindrical sections. Usual pipe friction formulae may be used to estimate the losses in cylindrical sections, taking due account of Reynolds number.

Diffusers. The losses in a diffuser section are a function of angle of divergence, expansion ratio, roughness, Reynolds number, Mach number and entrance conditions. In general, wind tunnel diffusers have divergence angles between 6 and 8 degrees, since angles of 10 degrees and above show tendencies for flow separation. Short diffusers may use larger angles than long diffusers.

Corners. The corners in wind tunnels are usually provided with a lattice of guide vanes which deflect the air as smoothly as possible through 90 degrees. The advantage of corner vanes is that they not only have relatively low losses, but they provide deflection with a minimum of velocity distortion. Some tunnels use gradual sweeping corners, but the resulting flow is usually distorted and has a spiral component. The loss in a corner without vanes may be approximated by hydraulic loss formulae for bends. The loss of the average corner provided with guide vanes is about 15 percent of the local velocity pressure, although there is a scale effect which tends to decrease this value for higher Reynolds numbers.

Nozzle. Losses in the nozzle are small since the flow is converging, and hydraulic formulae for friction losses may be used.

Power requirements. Power required to operate a subsonic wind tunnel varies approximately as the square of the diameter and the cube of the speed. Thus it is evident that power requirement is the chief factor limiting the utilization of large high-speed wind tunnels. As an example the N.A.C.A. full scale tunnel at Langley Field Va., has a test section of 30 by 60 ft with an 8,000-hp fan drive. The air speed is 118 mi per hr. To increase the velocity four times or to 472 mi per hr would require 64 times the power, or 512,000 hp. The most highly powered subsonic tunnel at present is the 40,000-hp tunnel at Wright Field. This has a 20-ft diameter throat and the air reaches a speed of 450 mi per hr.

Ventilation. With the increase of wind tunnel power the problem of dissipating the heat introduced by the fan drive becomes serious, since all of the brake horsepower goes into heat. One method of dissipating heat is by ventilation or air exchange. Ventilation of the test section was employed in an elementary form by the Moscow 3-meter tunnel in 1927 and the R. A. E. 24-ft wind tunnel in Farnborough, England. The D. V. L. 5×7-meter wind tunnel in Berlin used ventilation of the large section of tunnel by simple bleeding. The N. A. C. A. 8-ft high-speed tunnel utilized ventilation of the large section by means of an improved type of air exchanger with adjustable area. The Wright Field 20-ft wind tunnel, in order to dissipate 40,000 hp, has the highest degree of air exchange, namely 32 percent. In order to keep the exchange losses low, an air exchanger was developed whereby the discharged air passes through an annular diffuser around two 90-degree corners and is discharged into the atmosphere at low velocity.

Water cooling. Totally enclosed tunnels require auxiliary cooling, except where the horsepower input is low. Some tunnels use water-cooled corner vanes, while others such as the $5\frac{1}{2}\times7\frac{1}{2}$-ft Wright Brothers wind tunnel at M. I. T. and the N. A. C. A. 19-ft pressure tunnel, utilize shell cooling in the form of water sprayed on the outer shell surface. For still higher power in totally enclosed tunnels the surface area of shell plus vanes becomes inadequate for water cooling. In the case of the 12-ft Co-operative Wind Tunnel at the California Institute of Technology and the 12-ft Cornell Aeronautical Laboratory Wind Tunnel at Buffalo, water-cooled heat exchangers are installed in the large corner of the tunnel where the velocity is low.

Refrigerated Wind Tunnels

Where lower temperatures are required than water cooling affords, refrigeration is employed. Two systems now in use are: (1) Expansion coils in the tunnel circuit; (2) storage system whereby cold brine is circulated throughout the tunnel coils.

The leading example of the **direct expansion** method is the 20-ft altitude wind tun-

nel, at the N. A. C. A. Lewis Flight Propulsion Laboratory at Cleveland. This tunnel provides a throat temperature of −40 F at altitudes up to 50,000 ft. In addition, cooled and dehumidified make-up air can be supplied at the rate of 100 lb per sec to prevent contamination of the tunnel air due to exhaust gases when testing aircraft engines. An idea of the magnitude of the refrigeration problem can be gained from the fact that the connected horsepower required to drive the refrigeration compressors is 26,000 as compared with 19,000 for the fan drive proper.

The leading example of the **storage** system is the U.S.A.F. 10-ft high-altitude wind tunnel at Wright Field. This tunnel is provided with a 40,000-hp drive system and is designed to produce air speeds in the neighborhood of the speed of sound at pressures between one-tenth and two atmospheres and throat temperatures of −67 F.

A schematic diagram of the Wright Field 10-ft tunnel is shown in **Fig. 5.** Turbo-compressors with 2,500 connected hp, cool calcium chloride brine to −40 F in two 100,000-gal storage tanks. A third storage tank of the same capacity is normally empty when the system is not in operation. When the tunnel is running, cold brine from one of the tanks is pumped through a large heat exchanger installed in the low-velocity section of the tunnel, whence it is discharged into the empty tank and is cooled by the refrigerating system. When one tank of cold brine is exhausted, the second one is brought into use.

The capacity of the Wright Field system is designed to accommodate the full peak load of 40,000 hp for 1 hr of continuous operation, after which approximately 14 hr would be required for complete regeneration. However, since peak load operation will usually be for short intermittent periods, the capacity is considered adequate for continuous operation under normal loading conditions.

Supersonic Wind Tunnels

The previous discussion has been concerned with subsonic wind tunnels where

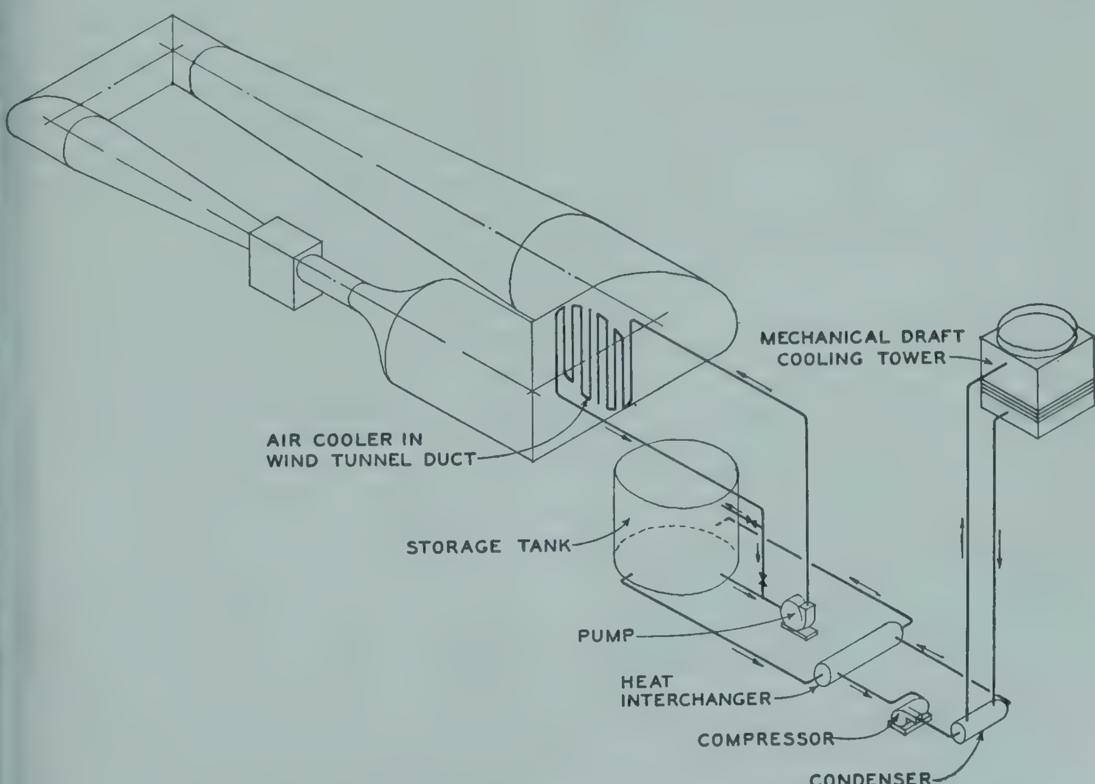

Fig. 5. Schematic Diagram of Wind Tunnel Cooling System.

the throat, which is the region of maximum air velocity, is the minimum area of the tunnel circuit. This is no longer the case for a supersonic wind tunnel, where the throat is preceded by a Laval nozzle. The higher the air speed, the greater the ratio of test section area to the area of the upstream constriction. Flow through a supersonic nozzle is associated with an adiabatic drop of pressure, density and temperature. Because of the low temperature of the air flowing through the throat, and the relatively high temperature level in the subsonic portions of the circuit, mechanical refrigeration is seldom required for the cooling of supersonic wind tunnels. Water circulation through conventional heat exchangers is usually satisfactory for cooling purposes.

One problem in supersonic wind tunnels which is more critical than subsonic is condensation. Due to the large adiabatic temperature drop in the tunnel throat, the moisture tends to condense, and the air flow is disturbed by the presence of condensation shocks. Therefore it is customary to dry the air in a supersonic wind tunnel quite thoroughly. Use of drying agents such as silicagel is often made for this purpose, although for some applications drying by refrigeration is advantageous.

Miscellaneous types of tunnels are as follows:

> **Icing.** In this type of tunnel, moisture is introduced through fine nozzles usually located in the large section upstream from the throat. Cooling coils are located either in the low velocity section of the tunnel circuit, or in an adjacent chamber through which part of the tunnel air is bypassed. Examples of icing tunnels are the small Goodrich Tunnel in Akron, the Ford Tunnel in Detroit, and the new N. A. C. A. icing tunnel at Cleveland.
>
> **Hot air.** Tunnels may be heated by heat exchangers or heating of the tunnel shell, but applications of this type are rare.
>
> **Dust.** Wind tunnels are used to study erosion by introducing dust or sand in the large section upstream of the throat.
>
> **Fire.** The purpose of this type of tunnel is to study the effect of air blasts on different combustion processes and especially to develop methods of extinguishing fires when they occur, for instance, in an airplane in flight.

It is seen from the above discussion that the wind tunnel can be visualized as a giant air-circulating system in which moving air at a series of different conditions of pressure, temperature, density and humidity is required at the throat for test purposes. It is concluded that modern wind tunnels present a new and interesting field for cooling and refrigeration on a large scale, and that interesting and stimulating modifications of normal air conditioning and refrigeration practice are necessitated by the stricter requirements of minimum pressure losses, optimum stream-lining and aerodynamic configuration, uniform flow distribution, wide range of operating conditions, and necessity for fine control and regulation of heat conditions.

BIOLOGICAL LABORATORIES

In the study of the origin, life history and the effects of environment and food on plants and animals, air conditioning is sometimes required. It is required for animal housing areas, special plant growth areas, cold rooms for storing volatile chemicals, viruses, media preparations, and special animal diets.

Design Conditions

In animal-study laboratories rats, mice, chickens, frogs, rabbits, guinea pigs, monkeys, dogs, cats, pigeons, and gophers are commonly housed. The usual human comfort standards are maintained in the offices and human work areas of these laboratories. Probably the most common standard is 78 F dry bulb and 50 percent rh. Animal housing areas are normally held at the same temperature and humidity as the offices; 78 F dry bulb and 50 percent rh is comfortable for most of the animals readily available in the United States.

Cold Rooms

In connection with animal housing and laboratory investigation, some cold rooms

dust-proof rooms, and vibration-free rooms are generally required. For storing volatile chemicals, viruses, media preparations, special animal diets and meats, walk-in boxes held at 35 F are provided. These boxes do not normally require special air treatment. The usual walk-in box type of installation and control is satisfactory. For storing viruses in an inert state, one or more small reach-in or walk-in low-temperature boxes are required. These boxes are normally maintained at −40 F. If desired, an anti-freeze solution may be circulated over the cooling coils in this room to accomplish continuous defrosting. If this is done the virus test tubes may be supported in the anti-freeze solution by means of a perforated plate.

In the study of micro-biology small dust-proof rooms are required. These rooms require low air motion and dust-free air; some are fitted with ultra-violet sterilizing lamps to sterilize the fresh air supply and the room atmosphere and contents. The sterile lamps are turned on for short periods before the experimental work starts. It is preferable to build these rooms of steel and glass and place them in the air conditioned area. Cooling may be accomplished by conduction through the walls and by the wiping effect of air circulated in the room. Ventilation air may be taken in through a filtered opening in the bottom of the partition and exhausted at the ceiling with the heat from the occupants and bunsen burners.

In addition to the cold rooms some sections of the laboratory may require special treatment. For example, rooms in which syphilis experiments are made are maintained at 60 F and 50 percent rh. It is reported that the percentage of successful infections was greatest under these conditions.

Many laboratories are equipped with chemical exhaust hoods. Conditioned air is supplied to these areas in the usual manner, but no air is allowed to recirculate. The type of ductwork used depends on the chemicals used. Tile lining is required in some cases.

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76. MILITARY APPLICATIONS

FOUR packaged air conditioning units more or less standard have been ordered by the military services for use in tropical areas around the globe; these will be discussed individually with a brief description of each.

Hospital Air Conditioners

Units for air conditioning hospitals are all of 5-hp motor-driven type suitable for 220-volt, 3-phase, 60-cycle current or 400-volt, 3-phase, 50-cycle and involve comparatively slight modification from standard commercial units of like size. They are used in large numbers in theatres of operation for operating rooms, some recovery rooms, X-ray development, dark rooms and the like.

These units use Freon-12, and include reheat coil using exhaust-condenser water to obtain accurate humidity control. A suction pressure regulating valve prevents the dew point of leaving air from dropping below a predetermined setting. Many of these units are to be used singly, one to a conditioned area; they are also applicable in multiple for larger areas.

The units are completely charged with refrigerant and self-contained, requiring no field assembly. However, forced draft cooling towers are likewise furnished as a separate item with each air conditioning unit, and these entail the field installation of a few feet of interconnecting water piping. A novel feature is that the sump tank is of sufficient size to require refilling only once in 24 hr, which permits the fan section to be collapsed into this tank to save shipping space.

These units with towers are to be installed exposed to the elements. The air inlet for fresh air is one half the size of that for recirculated air which for normal operation establishes the ratio of one-third fresh air and two-thirds recirculated. To avoid complex controls there is a steel slide making it possible to blank off entirely the return-air grille. Hence, for use in operating rooms under special circumstances the units may become at will "100 percent fresh air," in which case the size of the opening prevents overload.

Field Shop Units

Another type of unit made for the Navy by a different manufacturer is used for advance base workshops. This unit is furnished in two models—one for use in parachute drying towers, and the other for temperature and humidity control in optical and bombsight repair shops, as well as photographic, V-mail and photolithographic laboratories or any other spaces requiring close control of air conditions.

Both models are self-contained and factory-assembled on a rugged frame to withstand rough handling. Field installation is extremely simple, requiring only an electric power connection, because each model is equipped with air condensers and a panel with all necessary controls.

The **parachute-drying** unit is powered by a 3-hp electric motor, while the other unit requires a 5-hp drive.

An unusual feature of the parachute-drying unit is the use of the air condenser to furnish all of the reheat required for drying purposes. The dehumidifying coil is equipped with a manual air bypass to al-

JOHN M. LAMBERT, Author Chapter 76. Born 6/26/1900 in Philadelphia, Pa. Educated at University of Pennsylvania, 1922; graduate courses at Drexel Inst. of Technology; Pennsylvania State College. Formerly, Draftsman, Erecting Engineer, Estimator, Application Engineer, and Branch Office Manager in various eastern cities, York Corporation; Refrigeration Consultant to War Production Board, 1943–44; Director of Contract Terminations, York Corp.; Manager, Washington office, 1946.

Member, Baltimore Engrs. Club, 1935–39; ASRE Baltimore-Wash. Section Executive Committee: ASRE Awards Committee, 1948, Chairman, 1950; Program Committee, 1949.

At present, Manager, Consumer Sales, York Corp., York, Pa.

low field adjustment of the dehumidifying effect.

The **temperature-and-humidity-control** unit is identical to the parachute unit, except that two air condensers are furnished in series with the reheat coil, and a modulating face and bypass damper assembly around the hot gas reheat coil furnishes means for modulating the discharge air temperature under thermostatic control. No hot gas solenoid valves are required.

Both units are equipped with humidistats to control the refrigeration.

Filtering dust from the air is a necessary function of these units, and each one is provided with a generous filter area for both outside and return air.

This equipment is rugged, requires little skill for field installation, yet provides the good temperature and humidity control needed in adjusting and repairing the delicate parts required for modern warfare.

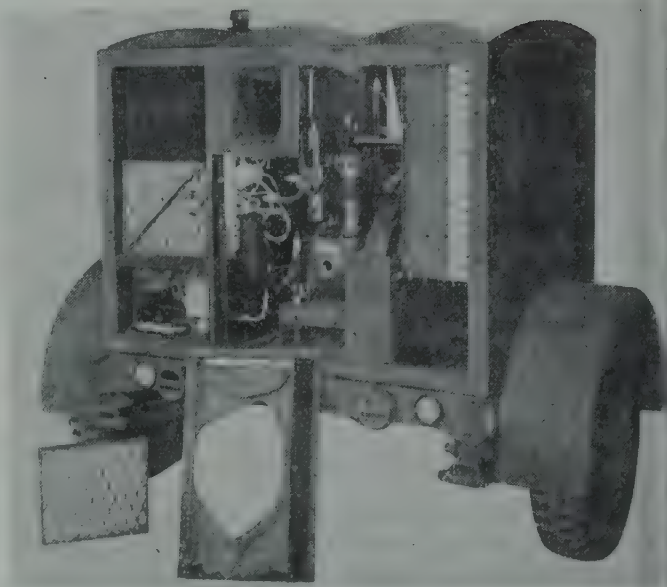

Fig. 1. Unit for Field Air Cooling.

Marine Corps Trailer Units

These mobile dehumidifying units, designed to meet the requirements for air conditioning mobile position-finding equipment and occasionally photographic equipment have no commercial counterpart. Air conditioning, particularly **dehumidification** of the operation trailer containing costly and delicate instruments, is necessary to prevent deterioration and severe reduction of accuracy. The bodies of these trailers were already so compactly designed that it was mandatory to treat the dehumidifying units as secondary trailers to be brought along side the main operation trailers when stationary and connected by flexible canvas ducts. A weight limitation of 2,000 lb, including trailer, was established and met in the design of this unit. The two-wheeled trailer is built, insofar as practical, with standard jeep parts. Since the unit had to be completely self-contained and independent of external power or water service, the drive is by gasoline engine and the condenser is air-cooled.

The equipment functions in this fashion: After being hauled over rough roads where a very low center of gravity prevents capsizing, we will assume the location has been reached for the caravan to become temporarily stationary. The dehumidifying unit is rolled close to the side of the operation trailer and the canvas supply and return air ducts are connected to the openings provided in the body of the truck housing. The gasoline engine is hand-cranked and the unit is immediately in operation.

The supply fan delivering conditioned air to the truck body is V-belt-driven from the gas engine, as are the condenser fan and the water-cooled engine radiator fan in addition to the Freon-12 compressor. Accurate humidity control is accomplished by means of a reheat coil supplied with hot water from the engine radiator, regulated by a self-contained, modulating thermostatic valve with the sensitive element located in the return air stream.

The extreme requirement of conserving weight and reducing size drove the designers of this unit to a finished product 52 in wide × 38 in. long in direction of travel × 40 in. high, mounted on a two-wheel trailer having a 62½-in. center-to-center-of wheels dimension and a supporting platform 27 in. above ground. The capacity is 26,500 Btu per hr when supplying 1000 cfm of conditioned air, of which 900 cfm is re-

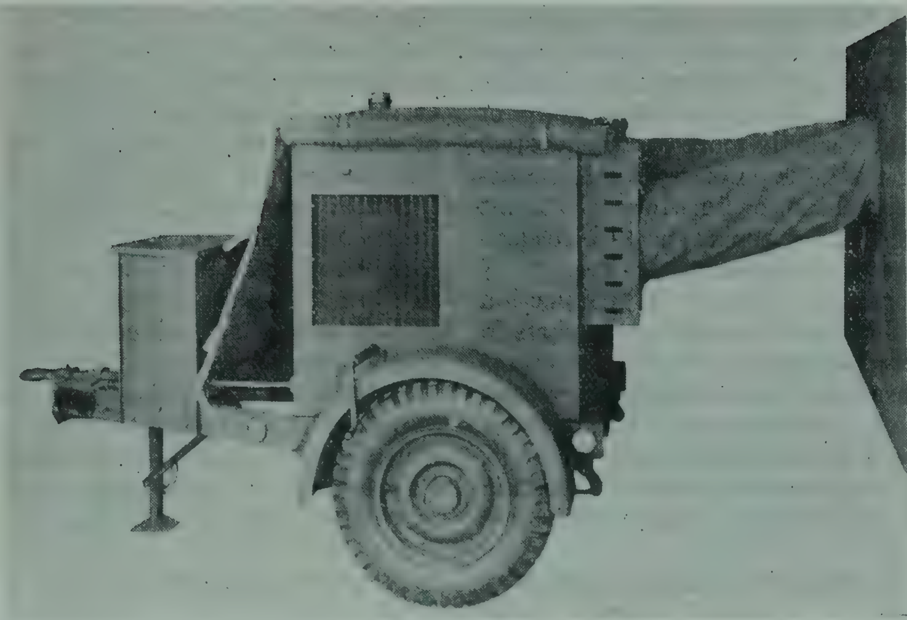

Fig. 2. Mobile Air Conditioning System.

urn air at a temperature of 80 F dry bulb nd 67 wet bulb; 100 cfm is fresh air at a naximum of 105 F dry bulb and 80 wet oulb. The unit is also capable of operating t 120 F ambient temperature. One of the eatures dictated by weight conservation is he enclosure of the unit with roll-up canvas panels to permit access to the equipnent and free flow of air to the condenser nd radiator fans when in use.

Signal Corps Dehumidifying Unit

A war-developed unit for operation in 10 F ambient temperature, the Signal Corps dehumidifying unit, has a capacity of 26,000 Btu per hr with 75° wet bulb ir through the evaporator, to meet the equirements of stationary radio sending nd receiving equipment where humidity n excess of 50 percent sustained for 20 nin would make some of the delicate instruments inoperative. Since condensing water was assumed to be not available, aircooled condensers were provided and the compressors driven by V-belts from 3-hp ropical wound motors.

Compactness of the installation was denanded, the result being a unit 58 in. wide × 57 in. long by 27½ in. high, gross weight about 1985 lb.

The design is such that 13 in. of the unit extends into the conditioned space; the remainder, containing all the working parts, projects through the wall and extends outside the building. The joint between the air unit and the wall is sealed in the field. To meet the demands for lack of vibration, the compressor motors are spring-mounted with flexible connections in the suction and discharge line, and a statically balanced condenser fan is furnished.

The framework of the unit consists of steel angles enclosed in steel panels, and the refrigerant is Freon-12, the initial charge per unit being about 25 lb.

Summary

All of these units are for use around the world under the most severe atmospheric conditions, far removed from the point of manufacture. Although every effort consistent with the requirements has been exercised to obtain simplicity and ruggedness of design, some maintenance and repair by inexperienced personnel is inevitable. This situation is met by the requirement of exceedingly elaborate manuals of description and a comprehensive complement of spare parts to accompany each unit. In most cases these spares are divided into two separate groups and occasionally

three. The "A" or first group of spares accompanies the unit and includes items capable of simple replacement by the operator. The second or third group of spares is increasingly more comprehensive, extending to the type of repairs to be accomplished behind the lines in a permanent or semi-permanent repair shop by reasonably competent mechanics.

The **corrosive damage** in connection with the shipment of initial spare parts in the African campaign, where the crates were exposed to the weather for long periods of time, or occasionally totally submerged, was greater than battle damage. This motivated change orders on existing contracts and a fixed procurement policy thereafter to the end of very special protective treatment for spare parts susceptible to corrosion. Included are the spraying of certain parts with a rust inhibitor, greasing of certain parts, immersing them in wax and sealing in waterproof paper. This treatment applies particularly to and becomes a problem of greater magnitude in connection with gasoline engines and repairs and replacements for these engines. In fact, this spare problem loomed so large in the minds of the military authorities that the total spares generally approached 35 per cent of the value of the unit, and contracts stipulated that units not be shipped in most cases except accompanied by their complement of spares.

If you searched this chapter for something which was not found in it, please let the editors know.

77. PRINTING PLANTS

DRINTERS are interested in air conditioning primarily as a means of solving ome of their most troublesome operating roblems. Paper, the principal raw material sed in printing, is very sensitive to variaions in the humidity of the surrounding ir and to extreme conditions of humidity nd temperature, as are some of the other aterials and operations. These variations nd extremes result in operating difficulties which interfere with production, and lower he qualities of the finished products to n extent that cannot be tolerated in a nodern plant. A conditioning system of he correct design, if properly operated, vill provide satisfactory solution of the roblems involved by removing the causes f the disturbing effects. However, the tmospheric requirements of some processes of printing are exacting, and very areful consideration of the problems peculiar to the process in use is essential in alculating the needs of a specific plant.

The **principal processes** of printing that equire separate consideration when planing air conditioning are: multicolor offset ithography; all other sheet-fed processes, ncluding letterpress, sheet-fed gravure, vet-process color printing, and engraving; nd newspaper and other web-fed printing.

CHARLES G. WEBER (deceased), Author Chapter 77. Born 10/12/93 in South Wales, New York; died 1/18/49. Educated at N.Y.S. College of Forestry, BS, 1916. Served in U. S. Army, World War I. Mill Operator, Beaver Board Co., 1919–21; Sweet Bro. Paper Mfg. Co., 1923; Forester, Burlington Basket Co., 1923–28; Paper Technologist, Assistant Chief Paper Section, National Bureau of Standards, 1928–49.

Author of 46 articles in Natl. Bur. of Standards publications and other journals, dealing mainly with papermaking materials and processes, printing, packaging materials, low-cost housing materials, standardization of testing methods for paper and related products, and use of microfilms for records.

Member, Technical Assn. of Pulp and Paper Industry; Amer. Society for Testing Materials; Society of Motion Picture Engineers, and served on standardizing committees of these organizations.

Reviewed by B. W. Scribner, Chief, Paper Section, U. S. Dept. of Commerce, National Bureau of Standards, Washington, D. C.

Few of the problems are common to all processes, and the weather control required for one is not necessarily suitable for another.

It is the purpose of this chapter to outline the **conditioning requirements** of the different processes, and to show the degree of atmospheric control that will reduce production difficulties to the minimum. The performance required for optimum results for each process is discussed to assist the engineer in the design of suitable equipment for any kind of printing plant.

The refrigeration requirements of a print shop are determined by the cooling necessary to maintain constant wet and dry bulb temperatures. The control of **relative humidity** is of utmost importance. Central-station plants for conditioning the air of the entire building or the area desired within the building have proved most successful, and the dew-point system of maintaining constant relative humidity, with refrigeration for dehumidification, is applicable to all printing plants. This system combines heating, ventilating, dust removal, and air conditioning in one system, and provides the required relative humidity and temperature throughout the year, which is highly desirable.

It is necessary to consider the relationship between the atmospheric conditions in the plant and the behavior of the materials in the printing processes. **Symptoms** of disturbing weather conditions include: distorted, curling, and buckling papers; static electricity; misregister of color prints; ink set-off and ink misting; troubles with composition rolls; and the distortion of wooden cutmounts, or the wood blocks used to mount half-tone cuts. These difficulties result from the reactions of paper and other hygroscopic materials to atmospheric variations or extremes.

Paper Characteristics

Since paper is hygroscopic, its properties vary with the amount of moisture it holds.

The dimensions of paper are always affected by its hygroscopic moisture through swelling of the individual fibers. Changes of dimensions are directly responsible for most register difficulties in lithography and are indirectly responsible for production difficulties in all sheet-fed printing through the formation of various forms of distortion. Wavy edges and **buckling** are common and very troublesome forms of distortion. They are caused by the uneven distribution of moisture across the sheets, resulting from the gain or loss of moisture at the edges of a pile. Wavy edges develop when paper in a pile or stock is exposed to an atmosphere that is relatively moist. The exposed edges absorb moisture and expand to cause the wavy effect. Tight edges and buckling are caused by exposing piles of relatively moist paper to air that is dryer than the paper. Loss of moisture from the edges causes them to shrink and tighten, and this shrinkage causes the sheets to bulge in the center or buckle.

Curling is a common defect of paper that results from structural stresses which are exaggerated by hygroscopic moisture. The causes are numerous and often complicated, but it can be said that the tendency to curl is always greatest when the relative humidity is lowest. Paper becomes brittle at low humidities, particularly coated paper. At high humidities, paper loses tensile strength and is easily stretched. All of these facts indicate that the relative humidity selected for the handling and printing of papers should be somewhere near the middle of the range, preferably between the limits of 40 and 60 percent. Temperature, per se, has little measurable effect on the properties of paper, and consideration for the health and comfort of the workers should determine the selection of the temperature to be maintained. It is not necessary to maintain the same temperature winter and summer.

Static electricity charges are built up on dry paper as the result of friction and pressure incident to printing. Static electricity interferes with the feeding of a press and may clog the delivery end. It also causes much troublesome set-off of ink by making the sheets cling together. If the relative humidity of the air in the pressroom is not allowed to fall below 4 percent, the conductivity of the air wil prevent charges from building up, becaus the electricity will be dissipated as rapidl as it is generated.

Rollers and Inks

Printers' composition rolls are commonl made of a mixture of glue and glycerine The composition, being highly hygroscopic is very sensitive to weather changes. In a atmosphere of low humidity, the rollers dry out and crack; at high humidities they swell, become soft, and lose thei affinity for the pigment of the ink. Eithe condition makes satisfactory press operation impossible. For completely satisfactory performance of rollers, the humidity

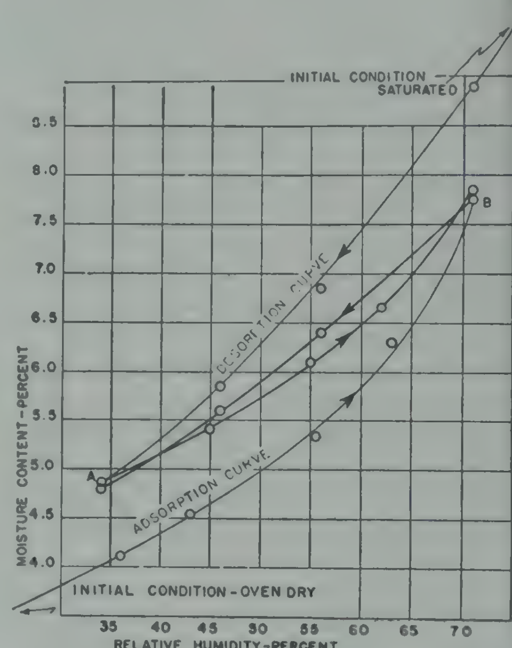

Fig. 1. Equilibrium Moisture Content of Papers at Different Relative Humidities.

must be maintained at some point between the same two extremes mentioned for paper, namely 40 and 60 percent. Temperature also affects rollers. They become soft and sticky at excessively high temperatures and at low temperatures are too hard to distribute the ink properly.

Ink viscosity varies with the temperature, and it is very difficult to obtain uniform printing results without controlled temperature. Variations may result in

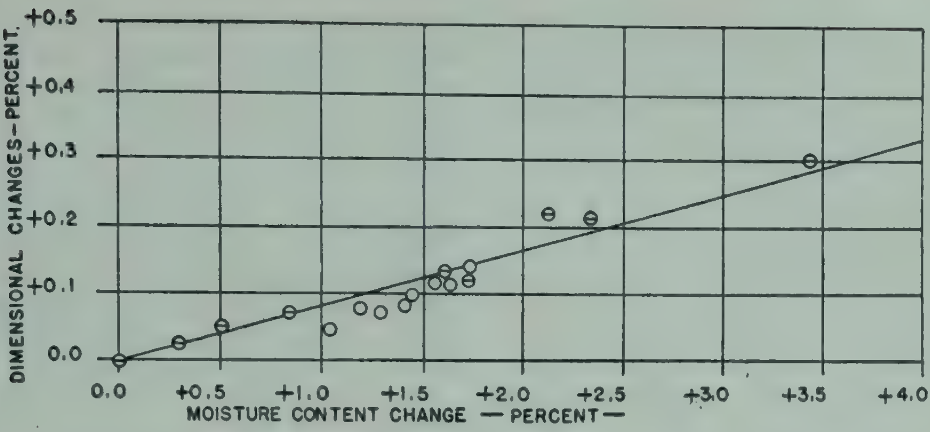

Fig. 2. Effects of Variations of Moisture Content on Dimensions of Printing Papers.

ither loss of color density or in picking. Che effects of humidity variations are more ndirect. High moisture content in the aper slows up absorption of the ink ehicle and thus retards the drying and auses set-off of the ink. Also, lithographic nks lack gloss and two-tone inks tend to pread or "feather" when printing paper hat is in hygrometric balance with relative umidity above 60 percent.

Multicolor Offset Lithography

The humidity requirements for multi- olor offset printing are more exacting than or any other process of printing. Here, the limensions of the paper must remain con- tant during a complete printing, which nay comprise from three to 20 or more rips through a press, and may require a veek or more for completion. Failure of the aper to retain its dimensions is the most mportant cause of poor register.

In many classes of color printing, expan- ion of paper amounting to one-fiftieth of ne percent of its length during the print- ng will have serious effects, and a change f that order will result from a slight varia- ion in the moisture content. The moisture ontent of paper is controlled by the hu- nidity of the surrounding air, and there is straight-line relationship between the moisture content of a sheet and its length. These characteristics are shown in Figs. 1 and 2, respectively.

The primary requirement, therefore, of conditioning in this field of printing is to keep the moisture content of the paper constant. It is complicated by the fact that paper, conditioned to equilibrium with the pressroom air of a plant having constant humidity and temperature, will expand during printing due to absorbed moisture from the press because moisture is used on the printing plate. Solution of the problem requires special preparation of the paper. It must be in condition to lose moisture to the atmosphere during printing at the same rate that it picks up water from the press. When printing with a normal amount of water on the plate, this balance will be obtained if before printing the first color, the paper is conditioned to equilibrium with relative humidity 5 to 8 percentage points above that maintained in the pressroom.[13,17]

The choice of atmospheric conditions for a lithographic plant is not difficult. Any selected humidity between 40 and 55 percent can be made to give satisfaction in the pressroom, and 48 percent is considered optimum. The relative humidity in the paper stock room, where paper is conditioned for printing and stored, should be 5 to 8 points above that of the pressroom. Hence, the conditions recommended are 48 percent in the pressroom, and 55 percent where paper is conditioned and stored. Comfort and economy of operation should be the factors influencing the choice of temperature for the entire plant. The processing room, transfer and plate-printing rooms and other parts of the plant may be maintained at the same humidity and temperature as the pressroom.

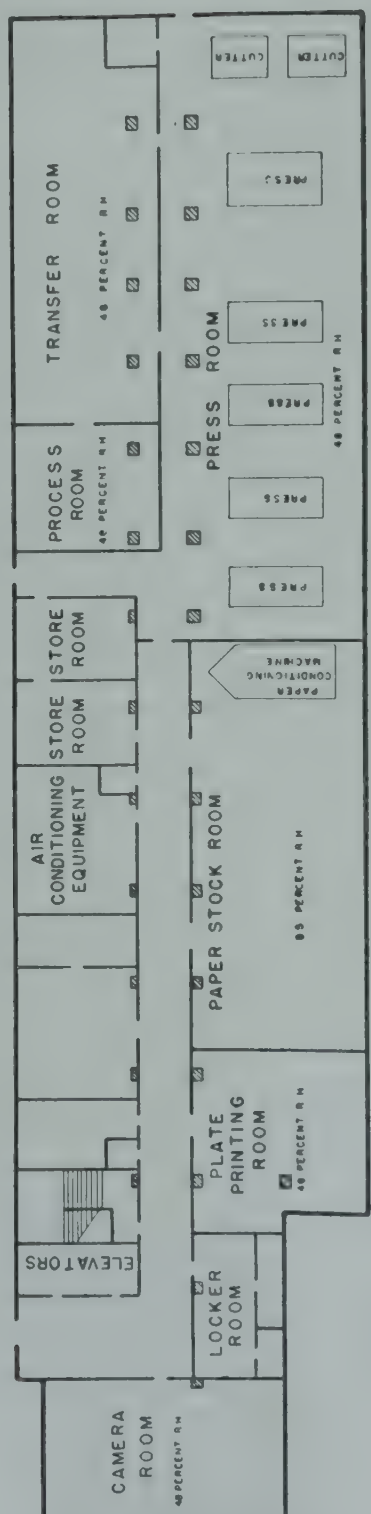

Fig. 3. Plan of an Air Conditioned Lithographic Plant with Single Dew-Point Control System.

Control for offset lithographic printin requires a selected humidity (48 and 55 per cent in the pressroom and paper stock roor respectively are recommended) within percent, and a selected temperature withi 5 F.

An example of well-planned conditionin is shown in **Fig. 3,** a plan of the lithographi plant at the Coast and Geodetic Survey Washington, D. C., where carefully planne conditioning facilitates obtaining fine regis ter with a minimum of spoilage at al seasons of the year.

Other Processes

All sheet-fed printing processes, excep multicolor offset lithography, which i treated in the preceding section, can b included in a single category. This is pos sible because the requirements with re spect to atmospheric control do not diffe essentially for the various kinds of printin included. In all of these processes, pape should be protected from variations an extremes in humidity and temperature t prevent wavy edges, curling, and buckling so that it will feed properly and stay flat Expansion and contraction of the pape are not important except as they affec distortion, hence the special preparatio required for multicolor lithography is no needed. The hygroscopic wooden cut mounts and composition rolls are used and the control of static electricity is im portant.

The selection of atmospheric condition must be based on a consideration of thes factors. It is safe to say that the choice o humidity is limited to the range of 40 t 55 percent; 50 percent is recommended This humidity apparently yields best re sults with paper, composition rolls, an ink, and it satisfactorily prevents the ac cumulation of static electricity. The con trol required for all sheet-fed printing except multicolor lithography, is a selecte humidity between 40 and 55 percent (5(percent preferred) within 5 percent, plu or minus, and a selected temperature with in 7 F, plus or minus.

The conditioning problems of processe using paper in roll form, referred to a web-fed or web printing, are in a sens different from those of any sheet-fed proc-

ess. Here, low humidity produces the most serious difficulties attributable to uncontrolled weather. It causes paper to lose moisture from the ends of the rolls and contract. This localized contraction produces "short" or "tight" edges, and paper in this condition is prone to develop edge cracks which cause excessive breaking of the web on the press. Also, static electrical charges and ink "misting," particular enemies of this type of printing, are always associated with dry atmosphere. Hence, the importance of avoiding the damaging effects of dry air is apparent, and a higher relative humidity is recommended for this class of printing than for others. Here, the humidity recommended is 55 percent.

The control required for newspaper and other roll printing is thus a selected humidity (55 percent recommended) within 5 percent, plus or minus, and a selected temperature within 10 F, plus or minus.

Pointers on Operation

The mere installation and operation of a conditioning system will not necessarily bring anticipated results, even though it functions perfectly from an engineering standpoint. To secure the kind of results that printers expect from expensive equipment, it is essential that the conditioning of paper be given ample attention. Several of the most troublesome difficulties can arise and persist even under ideal atmospheric conditions if the paper is not given the proper treatment.

Paper received at the printing plant is, or should be, **protected** with moistureproof wrappers. The wrappers should never be removed or even broken while the paper is colder than the surrounding air as it often is during the winter season. This is extremely important, as cold paper will absorb moisture so rapidly, due to condensation from the surrounding air, that it will become distorted almost instantly. When, after temperature equilibrium is reached, the wrapper is broken, all paper in sheet form should be conditioned immediately if its moisture content is not already properly adjusted for printing.

The conditioning of paper in sheets can be accomplished by hanging it in small lifts of 25 to 50 sheets each and blowing air up between the sheets. Conditioning machines are convenient for this purpose as they provide more efficient circulation of air around the paper than can be secured by other means, and moisture can be added directly to the air stream by means of moistening devices. It is not practicable to condition roll paper by methods at present available.

The sword-type of paper **hygroscope,** which was developed by R. F. Reed of the Lithographic Technical Foundation, is an indispensable tool for checking the hygroscopic condition of paper relative to the surrounding air. Knowledge of this relationship is essential at every step in printing paper in sheet form. The instrument resembles a sword in shape, and the blade contains a moisture-sensitive element. Expansion or contraction of the element actuates the pointer in a dial mounted on the handle. In use, the instrument is waved in the adjacent air until the pointer comes to rest and the dial is set to give a zero reading. The sword is then inserted into the paper and the movement of the pointer from the zero reference mark indicates the moisture condition relative to the surrounding air.

Fig. 4 illustrates sword readings taken on three piles of paper in a pressroom. The first indicates that the paper is far too dry to be exposed to the room atmosphere without the formation of wavy edges. The second reading indicates that this paper is in equilibrium with the air which is correct for all sheet-fed printing except multicolor lithography. The third was taken on paper

Fig. 4. Sword Hygrometer Readings Taken from Three Lots of Paper.

that was "wet" relative to the pressroom air. This pile had been conditioned to equilibrium with the air in the paper stock room where the relative humidity was seven points above that in the pressroom, where the reading was taken and, there-

fore, was in optimum condition for multicolor lithographic printing.

Summary

Air conditioning is highly desirable for every kind of printing and type of printing plant. Its most important function is to facilitate obtaining maximum results with paper, which is highly hygroscopic, and this is done by maintaining constant relative humidity.

The benefits to be expected for print shops in general are: Improved register of color prints; elimination of static electricity; reduction of expansion, curling, buckling, and web-breaks of paper; control of ink viscosity; stability of dimensions of wood mounts; and improved life and performance of composition rolls. These make for elimination of spoilage, increased production, and better quality of products.

The conditioning requirements of a specific plant are determined by the printing processes used. Multicolor lithography, all other sheet-fed processes, and web-fed printing are the categories requiring different atmospheric conditions and control.

The success of air conditioning in printing plants is contingent, to a large degree, on attention to the treatment of the paper. Adequate moisture conditioning of the paper is as important as the regulated operation of the air conditioning system.

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If you searched this chapter for something which was not found in it, please let the editors know.

78. REFRIGERATION AND AIR CONDITIONING FOR CANDY MANUFACTURING

REFRIGERATION for all candy manufacturing has long been recognized as an essential requirement for successful operation. In a stricter sense, it is more exact to consider that the real tool for the manufacturer is air conditioning. It follows that of necessity, in the temperature and humidity ranges encountered in this industry, refrigeration is a necessary part of the air conditioning system. There are relatively few straight refrigeration applications as contrasted to the many departments benefited by proper control of its atmosphere, all of which results in high production, low production cost, quality and uniformity of product.

Most of the materials used in candy manufacturing are sensitive to temperature or relative humidity, or both. A properly controlled atmosphere at the optimum condition for the process then becomes a primary means of controlling the solidifying, crystallization, physical properties, quality, and appearance of the finished product.

No hard and fast rules can be laid down for the design and application of air conditioning to cover all the needs and product formulae that exist in the manufacturing of candy. Each specific job requires careful engineering analysis to assure success for a specific requirement. Basically it must be borne in mind that the primary consideration is the product, but the design engineer must not lose sight of the fact that the comfort of the worker is important and must be considered in the final design of the system.

In general, there are several more or less standardized departments or operations, one or more of which will be encountered in every plant. There are various general principles of design, ranges of conditions, and peculiarities that apply to these processes. These are:

1. Hot Rooms
2. Cold Rooms
3. Cooling Tunnels
4. Coating Kettles
5. Packing, Enrober, Dipping Rooms, etc.
6. Storage.

Sensible heat must be absorbed by the air conditioning apparatus employing chilled air in a well designed air distribution system as well as plates, tables, cold slabs, in tunnels or other similar coolers. In calculating the loads, the usual sensible heat sources must be considered such as people, power, lights, sun effect, transmission losses, infiltration, steam heating apparatus and the heat of the product as it enters the space to be conditioned.

Table 1 summarizes the usual design conditions for refrigeration and air conditioning processes.

The formulae used in making candy, as well as the cooking processes and temperatures, are of course numerous. However,

JACK E. SALMON, Co-Author Chapter 78. Born 7/17/12, in Chicago, Illinois. Educated at University of Michigan, BS, 1934. Formerly, Jr. Engineer, M. H. Detrick Co., 1934–35; Engineer, Carrier Corp., 1935–38; Sales Engineer, 1938 to date. Instructor for Refrigeration Short Course held by the Amer. Bottlers of Carbonated Beverages at University of Illinois, 1948–49.

Author "Air Cond. and Refrign. in Candy Manufacturing," Associate Retail Confectioners Souvenir Program, 1945; "Refrign. for the Bottler," *Bottlers Gazette*, 1949.

Member, Amer. Soc. of Refrig. Engineers; Tau Beta Pi; registered professional engineer, State of Illinois.

At present, Sales Engineer, Carrier Corp., Chicago, Ill.

WILLIAM S. BODINUS, Co-Author Chapter 78. Born 2/24/09 in Chicago, Illinois. Educated in Illinois Inst. of Technology, BS, 1935. Formerly Mechanical Engr., Thielbar and Fugard, 1926–29; Refrig. Engr., Brunswick-Kroeschell Co., 1929–30; Engineer, Salesman, Branch and District Manager, Carrier Corp., 1930 to date.

Contributor to Refrign. Service Manual, 1941; Brewery Refrign., 1933; numerous articles on refrign. and air conditioning engineering and application.

Member, Amer. Soc. of Refrig. Engrs.; Chairman, Chicago Section, 1945; Amer. Soc. of Heat. and Vent. Engrs.; Heating, Piping and Air Cond. Contractors Assn.—Chairman Air Cond. Committee; registered professional engineer, State of Illinois.

At present, District Manager, Carrier Corp., Chicago, Ill.

Table 1. Usual Design Conditions*

Department or Process	Design DB (°F)	RH (%)
1. Hot (Dry) Rooms		
a. Gums	140–160	—
b. Jellies	120–140	—
c. Marshamallows	75	45
2. Dipping Rooms	65	55
3. Packing Rooms		
a. Hard Candy	65	45
b. Chocolate Goods	65	55
4. Enrober Room	80	55
5. Storage		
a. Nuts	30–35	75
b. Chocolate	60	55
c. Finished Goods (General)	65	50
d. Hard Candy (Bulk)	75	45
6. Cooling Tunnels (Supply Air Temperatures)		
a. Centers for Enrobing	50	—
b. Enrober	40	—
c. Hard Candy	55	—
d. Cast Chocolate	45	—
7. Coating Kettles (Supply Air)	95	15

* Conditions given in this table are intended as a guide and represent average values which have been foun to be satisfactory for many installations. However, specific cases may vary widely from these values due to suc factors as type of product, formulae, cooking process, method of handling, time, etc.

two of the basic ingredients are sucrose and glucose, and in some instances dextrose is used. These products are somewhat unstable in that they may easily change from a crystalized form to a fluid or liquid depending upon temperature or moisture content, or combinations of the two. The surrounding temperature and humidity, therefore, must be controlled to establish the regain or equilibrium moisture and thereby regulate the crystallization and grain structure. Temperature should be relatively low for most installations, generally below 70 F. The relative humidity at 70 F is usually 60 percent or less, depending on the type of sugar used. Where chocolate coatings are used, temperatures of 65 F or less are desired, again depending on the type of the chocolate.

The influence of formulae, for example, can be appreciated when one considers that for cream centers with a high percentage of sugar the most desirable room conditions are 85 F maximum with 50 percent relative humidity, while if similar centers are made from a formula containing a high percentage of corn syrup the maximum room temperature must be reduced to about 75 F. This is because corn syrup is somewha more susceptible to high temperature an has a higher regain than cane sugar.

Chocolate

Chocolate is one of the main ingredient used by the candy industry. It is produce separately in either bar or commercia block form and is used as one of the in gredients in the various types of cente materials as well as a coating for cand bars, creams, nuts, fruit, jellies, etc. Choc olate is an amorphous material having n definite and sharply defined congealin point. It solidifies gradually as the temper ature is decreased due to the freezing ou properties of the several fats of which it i composed. For practical applications, th freezing point of high quality sweet mil chocolate is taken at approximately 86 F At the other end of the scale, the lowe quality dark chocolate will freeze from 9 to 92 F. Actually these freezing points ar about the lowest temperature at which th particular grade and type of chocolate i sufficiently fluid to permit easy handling It has been found by experiment that con siderable latent heat of freezing will be re

moved as the chocolate is cooled down to temperatures as low as approximately 70 F. For average purposes, the latent heat of freezing of the usual grades of chocolate used in candy manufacturing will vary from approximately 36 to 40 Btu per lb while an average value for its specific heat may be taken as .56 Btu per lb before freezing and .30 after freezing. In any sizable application however, it is always best to run calorimeter tests on the exact grade and type of chocolate used in the actual process under consideration before arriving at the final load determinations.

Chocolate bars or commercial blocks are cast in metal molds after the tempering process. In this process it is desirable to cool the chocolate in the molds as quickly as possible in order to obtain the maximum amount of lustre or high gloss finish on the finished product. However, too rapid cooling particularly in the larger size of commercial blocks, which is a standard 10 pound cake, may cause checking or cracking which, while not serious from the standpoint of quality, adversely affects its appearance. Normal practice calls for chilling the metal molds before the warm liquid chocolate is deposited in them. These molds should be cooled to approximately 60 F which is low enough to permit quick setting at the mold surface and yet is high enough so that condensation problems on the molds do not become serious. Even then, the room containing the depositor should be sufficiently cooled to a dewpoint below the surface temperature of the mold so that there will be no possibility of condensation on the mold. After the chocolate is deposited in the mold, it can be moved either into a cooling tunnel for a continuous cooling process or the molds can be stacked up and placed in a cooling room provided with forced air circulation. In either case, the temperatures of 40 to 50 F are satisfactory. It is important, however, that either the discharge room from the cooling tunnel, or the room to which the molds are transferred for packing, be maintained at a low enough dewpoint so that again no condensation is possible on the cooled chocolate goods. Such condensation will tend to dissolve some of the sugar content which eventually results in a blooming or graying of the surface. In figuring the loads for the cooling tunnel or cold room, it is necessary to account for the transmission and infiltration losses plus any load derived from further cooling of the molds and the sensible and latent heat cooling loads on the chocolate itself.

Chocolate Coating

In the modern candy plant chocolate coatings are applied to the center material in one of two ways. In the coating process, the center material is either formed by hand or cast in starch or rubber molds and is then dipped by hand or mechanically coated. The supply of chocolate for hand dipping is kept in a pan that is normally maintained at the lowest possible temperature to secure sufficient fluidity for the process. This temperature is higher than the dipping room temperature and it is therefore, a heating process. The most modern plants now have electrically heated dipping pans which are thermostatically controlled. The dipped candy to which the chocolate coating has now been added, is then either set on trays or on belts while the setting of the chocolate coating takes place. This setting is controlled by air conditioning the dipping room itself. As far as the setting of the chocolate is concerned, conditions of 35 to 40 F dry bulb would be best since these would promote rapid setting and result in a high gloss to the finished goods. However, most dipping is done by women and there will be large numbers at work in the dipping room and in consideration of their personal comfort, the temperature is raised so that they can work efficiently. This results in recommended temperature conditions for hand dipping rooms of 65 F dry bulb and a relative humidity not exceeding 50 to 55 percent. The principal problem in an application of this type is to secure even air distribution without objectionable drafts which would have an adverse effect on the workers. Calculating the loads for this type of installation requires, in addition to the normal loads such as transmission, lights and people, the heat load from the chocolate itself, all of which must be summarized with the heat utilized in the warming of the dipping pots.

For high speed production typical of bar

work, the chocolate coating is applied in a machine known as an enrober. This machine consists essentially of a reservoir for the fluid chocolate which is heated and thermostatically controlled to maintain the proper temperature of the chocolate. This chocolate is then pumped to an upper flow pan which allows it to flow in a curtain down to the main reservoir. An open chain type belt carries the centers through the flowlng curtain of chocolate where the covering is picked up. At the same time, grooved rolls pick up some of the chocolate and apply it to the bottom of the center. In this type of work, the centers should be cooled to 80–85 F to assist in freezing out and retaining the proper amount of chocolate coating. The coated pieces are transferred from the enrober to the bottomer slab and then into the enrober cooling tunnel. The function of the bottomer slab is to set the bottom coating as rapidly as possible in order to maintain this coating and form a firm base for the piece as it passes through the enrober tunnel. This bottomer slab often takes the form of a simple plate type evaporator which may be fed either with chilled water or brine or may be supplied directly with refrigerant. The belt carrying the candy passes directly over this plate and heat transfer must take place from the candy through the belt to the surfaces of the bottomer slab. The enrober tunnel serves to set the balance of the chocolate coating as rapidly as practicable consistent with high quality and good appearance of the finished goods. The discharge end of the enrober tunnel is normally in the packing room where the finished candy is then packed or wrapped as the case may be.

While not an absolute necessity, air conditioning of the enrober room is highly desirable. The principal reason for this is that the chocolate used in the coating process is exposed to the room atmosphere. Therefore, it is desirable that the atmosphere in the room be as clean as practicable and since filtration is a part of any air conditioning system, this in turn prevents the contamination of the chocolate with foreign material. When conditioned, it is advisable to maintain conditions of 80 F and 50 to 55 percent relative humidity. These conditions will be low enough to prevent the centers from materially warming up during the time they are exposed in the enrober room. The conditions will also assist in the setting of the chocolate coating after it is applied to the centers and as it passes over the bottomer slab which is also often located within the enrober room.

Bar Candy

Present day operations for the production of bar candy call for high speed semi automatic production in order to keep production costs to a minimum to meet the highly competitive market found in the bar candy field. In the production of bar candy the center material is delivered from the kitchen to spreaders which form layers on tables or this material is cast into starch molds. Depending on the composition of the center, the hot material may be delivered at as high a temperature as 160 to 180 F. Successive layers of different color or flavor may be placed one on top of the other to build up the entire center material. This will normally consist of nougat, caramel, marshmallow, whip, etc., to which may or may not be added peanuts, almonds, pecans or other nuts. Since each of the ingredients require different cooking processes, each separate ingredient such as caramel, nougat, etc., is normally deposited in a separate operation. Thus for example, a $\frac{1}{8}$ inch layer of caramel may be first deposited on which is then spread a layer of peanuts, followed by a $\frac{3}{4}$ inch layer of nougat; each of these layers being applied in a separate and distinct operation to build up the completed center. Normally it is necessary to allow some time for setting each successive layer, with the exception of the nuts, as it is deposited and prior to the application of each succeeding layer. If the centers are spread in slabs, the slab must first be cooled and then cut into pieces the size of the finished center. This is done by first cutting with rotary knives into blocks, the width of which equals the length of the bar. A second set of rotary knives then cuts the block crosswise into pieces having the dimensions of the finished center.

Hard Candy

Hard candy manufacture with high speed

ıachinery requires the use of air condiioning for the maintenance of both temerature and humidity. There is some diference in the requirements of candy made f cane sugar as contrasted to that which is ıade of glucose. For example, a temperaure of 75 to 80 F dry bulb with 40 percent elative humidity is satisfactory for plants ısing a high percentage of glucose, whereas he same temperature with a relative huıidity not to exceed 50 percent is necesary for cane sugar.

Where relative humidity is to be mainained at 40 percent or less, it is desirable o consider the use of standard dehydratng systems employing chemicals such as ithium chloride, silica gel or activated ılumina or other proven types that may be ıvailable. A combination of refrigeration ınd dehydration is an excellent type of intallation.

The quantity of air required is a direct unction of the sensible heat of the room ınd should be so calculated. Approximate ules indicate the quantity should be between 1½ and 2½ cfm per sq ft of floor area with a minimum of 15 percent outside air or 30 cfm per person. Consideration must be given to the sensible heat in the hard candy which is at a high temperature to keep it in a pliable condition during the forming operation.

Where concentrations of the finished product in containers or tubs are located in the general conditioned area, special consideration must be given to the increased quantity of air required in these areas to prevent sticking of the finished product.

Unitary type apparatus employing dry coils having a sufficient number of rows deep and adequate surface is satisfactory, or central station apparatus employing cooling and dehumidifying coils of similar design can be used. Good filtration is essential for air purity as well as for prevention of dirt accumulation on cooling coils. Reheat control is essential to sustained and constant temperature and humidity conditions.

Good air distribution is advisable with outlets spaced evenly throughout the area to insure uniform conditions and eliminate the possibility of drafts on the workers.

Starch Reconditioning

This is accomplished by using standardized starch drying equipment, and the starch employed in hot rooms and for other purposes is reconditioned and dehydrated in these units.

Hot Rooms

The drying of such products as jellies and gums can best be accomplished in air conditioned hot rooms. These products are normally cast by moguls into starch molds. The molds are contained in a tray approximately 35×15×1½ inches in size. The trays require an extra ½ to ¾ inch blocking at the bottom in order to provide space for air circulation. These trays are then racked up on trucks, the number of trays per truck being determined by the method of loading. Usual practice calls for approximately 25 to 30 trays per truck. The trucks are then loaded into the hot room where the actual drying is accomplished.

The normal drying temperatures for this type of product will average between 120 and 150 F dry bulb, and while the humidity is of importance, close control of this humidity is not necessarily needed since a check with psychrometric charts indicates that even with the maximum normal outside temperature conditions normally encountered, when this air is heated to 120 to 150 F, the relative humidity will be low—only from 19 to 13 percent. Most operators prefer to leave the humidity control under manual operation since in their regular inspection of the product during the drying process they can, from experience, determine whether the product is drying too fast or too slow and can then correct to increase or lower the relative humidity by varying the quantity of outside air.

The important problem in the hot room is one of air distribution and it is necessary to so arrange the product and the air flow so that the maximum amount of air will be in contact with the product. The first step in this is in the providing for space between trays as mentioned above. The second consideration is the location of trucks within the hot room. These must be so placed that a continuous flow of air from truck to truck can be assured with the shortest possible

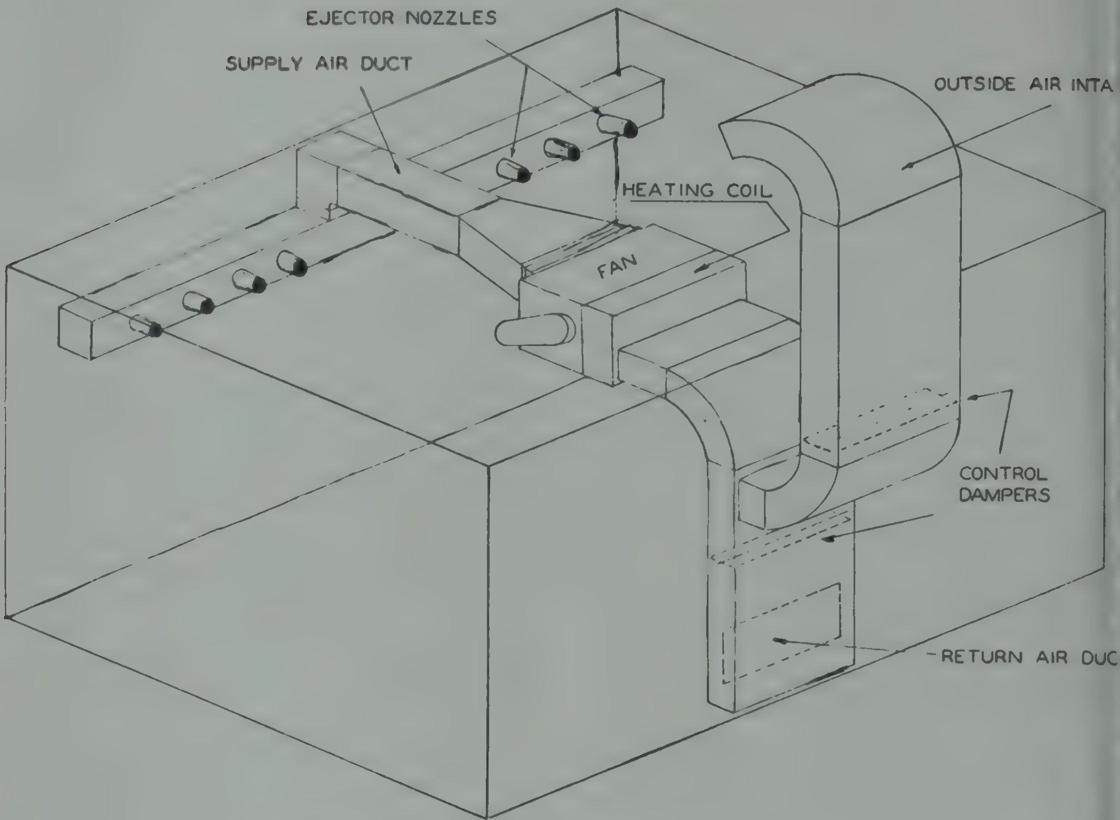

Fig. 1. Typical Arrangement of Hot Room System.

path for the air flow. In addition, adequate space must be maintained at the entering and leaving air sides in order to assure adequate flow from the top to the bottom tray for each truck. A large air quantity is required in order to secure uniformity over the entire product zone.

One method of securing this, and which has proven very satisfactory, is the ejector nozzle system, as shown diagrammatically in **Fig. 1.** Basically this system consists of a supply header fitted with conical ejector nozzles. These nozzles are so designed to have a tip velocity of 2000 to 5000 feet per minute with a static pressure behind the nozzle ranging as high as 1½ inches water gauge. Nozzles so set up will induce a flow of air about three times that actually supplied by the nozzles. This 3 to 1 ratio gives about the best economical balance between air quantity supplied and fan horsepower. By the use of an ejector system it can be noted that the primary and induced air streams mix over the product and sufficient space between the top tray and the ceiling must be allowed to permit this mixing. This mixing in effect rapidly decreases the necessary differential between the air supply temperature and the actual room temperature. The high air flow thus created tends to decrease the temperature drop across the product. Since the temperature drop is proportional to the heat pick-up, a greater air flow will therefore have a lower temperature drop, with the result that the spread between the air temperature entering and leaving the product zone is reduced. This in turn promotes uniformity of drying.

When drying is completed it is necessary to cool the product rapidly in order to facilitate unloading. A method of securing this quick cooling is provided for by a second outside air intake which by-passes the heating coil or the air conditioning unit. At the same time this by-pass intake is put into operation, drop dampers are opened in the bottom of the ejector header and this air then also by-passes the ejector nozzles and tends to flush out the heat in the room. The

se of an exhaust fan is also recommended or this part of the cycle in order to rapidly emove the heated air, which at this time ends to rise to the ceiling.

The equipment that is recommended for his type of operation consists of a fan and eating coil unit which may be suspended rom the ceiling inside the hot room proper r directly adjacent to it. This unit is provided with outside air intakes and ejector eaders as indicated above. Return air ampers are provided, as well as dampers, or the outside air intake. Most operators refer to use recording controllers in order o maintain an accurate record of each atch. This controller simply regulates the ow of steam to the heating coil in such a anner as to maintain the desired room emperature. It is usually advisable to proide gradual switches to control the posiion of the outside and return air dampers ince on a rise in humidity more outside air hould be taken, and conversely with a rop in humidity more return air should be aken. This function can be provided autonatically by a humidity control, but this is eldom used. An end position can be inluded on the gradual switch for the cooling down period so that under this circumtance the outside air damper is opened vide and the exhaust fan is started.

Cold Rooms

Many products in the confectionary inlustry require chilling and drying but cannot withstand high temperatures as indicated above under the subject of Hot Rooms. Typical products in this category are marshmallows, certain types of bar centers, cast cream centers, etc. In this type of work it is usually found necessary to maintain drying conditions of about 75 F and 45 percent relative humidity. The drying period of this type of product will vary from 24 to 48 hours. Basically, the system recommended is the ejector type outlined above for the hot rooms, the difference being that cooling coils are provided in the air conditioning unit. The load must be carefully calculated in order to arrive at the sensible and latent heat quantities from which the actual air quantity can be determined, together with air supply temperature, refrigerant temperature, etc. When properly balanced, the control of relative humidity becomes an inherent quality to the design of the system. The control system recommended is basically the same as for the hot room except that the recording regulator in this system must control the admission of steam to the heating coil in the wintertime or regulate the flow of refrigerant to the cooling coil in the summertime. The flushing dampers and cooling down cycle are of course unnecessary in this type of operation. There is, however, one precaution which must be observed in the equipment for the cold room and this is in connection with the starch or sugar dust that is normally picked up in the return air stream. Under the cooling cycle the cooling coil is normally condensing moisture and the accumulation of starch or sugar dust will rapidly form a paste on the cooling coil, which will seriously reduce its capacity and cause considerable nuisance in the maintenance and cleaning of the equipment. For this reason it is recommended that filters always be used to filter both the outside and return air entering the cooling coil.

Cooling Tunnels

There are various cooling requirements in the usual candy plant which can best be handled in a cooling tunnel. Typical of this work is the process of cooling coated centers after leaving the enrober, cooling of cast chocolate bars, and the cooling of hard candy. These operations are usually set up for a high rate of production and a continuous flow of product. Hence the product is normally conveyed on belts either through the enrober or the casting machine, as the case may be, and is then carried through a cooling chamber. Basically, a cooling tunnel consists of an insulated box placed around the conveyor in such a manner that the product travels through it in a continuous manner. Cold air is supplied to this enclosure in order to cool the product. To secure maximum heat transfer between the air and product it is usually desirable to employ the counter-flow principle whereby the air is introduced at the product leaving end of the tunnel and withdrawn at the product entering end of the tunnel in such a manner that the direction of the air flow

is opposite to the direction of the material flow. **Fig. 2** is an illustration of a typical cooling tunnel application employing these principles while **Fig. 3** shows a cold diffuser unit which can be readily adapted for this work. In general, air supply temperatures of 35 to 45 F have been found satisfactory for most of this type of work and velocities up to 2500 ft per min are normally employed. This high velocity improves the heat transfer and creates a turbulent condition in the air flow which gives further improvement in the heat transfer efficiency.

The actual size of the tunnel is determined from the size of the conveyor belt and the air quantity set up to give velocities in the order of that mentioned. The air quantity is dependent on the heat load and the rate of cooling desired; however, in general, it is wise to limit the rise in air temperature through the tunnel to 15 to 20 F maximum and it is good design to use one air conditioning unit for each tunnel. This unit normally consists of a fan and coil together with the necessary duct connections to and from the unit. Good practice requires an outside air intake since there are many times when the cooling can be accomplished with outside air at a saving in cost in operating the refrigeration plant. The tunnel should be made as tight as possible and the entrances and exits for the candy should be reduced to the mini mum practical point to limit the loss of a from the tunnel or air infiltration to th tunnel which would tend to upset the co ditions. In some cases it has been foun advisable to use a flexible canvas curta to accomplish this purpose. Some los however, is unavoidable, and it is therefo the general practice to take a small amou of outside air, or air from the adjoinin spaces, in order to provide a slight exce of pressure on the tunnel.

For chocolate enrobing work, the cond tion of the air is the paramount factor securing the best possible lustre on t chocolate together with an even coatin The best results are normally obtain with rather slow cooling but this in tu means either a low production rate or e cessively long tunnels, with the result th the final design is normally a compromis It is also essential that the chocolate be the proper condition at the time it poured over the centers since a too high too low temperature at this point will r sult in blushing or loss of lustre in the tu nel. This, however, is a function of the e rober machine and the operation of th machine. A similar phenomena is exper enced if the centers are too cold or too ho both conditions resulting in poor appea ance of the finished goods, and no amou

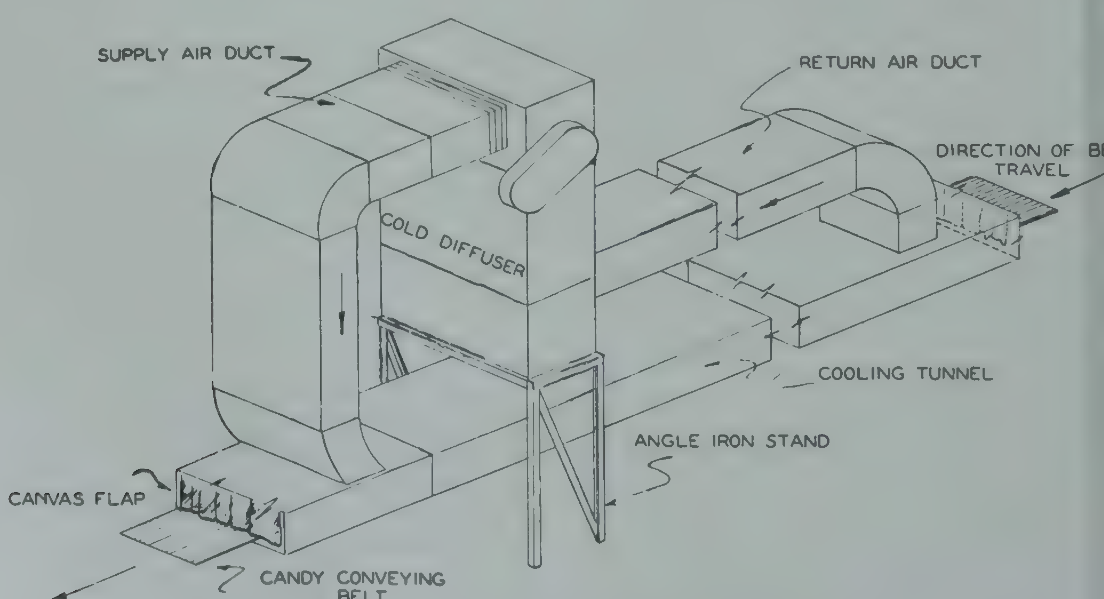

Fig. 2. Typical Candy Cooling Tunnel.

correction in the tunnel will compensate r this.

A variation of the standard single pass unter-flow tunnel has been used for enber work with good success. In this case e tunnel is divided horizontally by an uninsulated sheet metal partition. The belt rrying the candy rides directly on this rtition and the return belt is brought ck through the lower space below the rtition. The cold air is supplied to the wer chamber near the enrober and proesses to the opposite end of the tunnel here it is transferred to the top chamber. om this point it progresses in accordance th the counter-flow principle back to a int near the enrober where it is returned the cooling equipment. This tunnel has veral important features—in the first ace it chills the return belt so that this lt in turn can act in the manner of a botmer slab to give a quick setting of the se of the coated piece. The uninsulated rtition with the coldest air below assists this bottoming operation. In this manr the air supply has already absorbed me of its heat load by the time it is acally introduced to the product cooling ne proper. This effectively approaches e advantage of the slower cooling while ll keeping the tunnel to a minimum ngth.

Coating Kettles or Pans

The application of air conditioning to volving coating kettles or pans has proven be very satisfactory. Originally these ns were merely provided with a supply rather warm air, usually ranging from to 125 F. This air was then exhausted om the kettle to the room, and this eated a severe nuisance from the standint of sugar dust being blown out of the ttle. In addition, a portion of the energy quired to produce rotation of the kettle generates to heat in the centers being ated with the result that expansion may nd to produce cracking or checking. For is reason it is general practice to apply portion of the coating. Withdraw the oduct for a seasoning period, ranging up 24 hours, and then return the material the kettles for additional coating.

Installations have been made using a conditioned supply of air to the kettles and providing a positive exhaust system from the kettles. In this manner a large portion of the sugar fly problem is overcome. In addition the wet and dry bulb temperature of the air supplied to the kettles is closely controlled with the result that the rate of evaporation and hence the drying of the coating can be controlled to give uniformity with a high production rate and a lowered labor cost. Evaporation of the moisture in the coating material tends to take place at the wet bulb temperature of the air supplied to the kettle. In this manner a large portion of the heat of rotation entering the product is absorbed and overheating of the centers is not experienced. This eliminates the need for a seasoning period and it is possible to make a complete run without stopping which in some instances may be from 6 to 8 hours, depending on the nature and the amount of the coating applied. With air conditioning applied to coating kettles a very material reduction in the number of rejects caused by splitting, cracking, uneven coating or doubles can be accomplished. Recovery of sugar fly is accomplished by means of roto-clone or other similar dust extracting device.

Packing, Enrober, Hand Dipping Rooms, Etc.

There are a number of rooms or departments in every candy plant in which air conditioning is either an essential to production or can be shown to be a very good investment. As long ago as 1925 one authority on candy production stated, "One of the prime requisites of successful packaging is conditioned air." The average manufacturer spends considerable time and effort in the correct design and application of packing and packaging materials for his product since it is recognized that this one item very materially affects the keeping quality of the goods. The end result is to provide more nearly moistureproof containers as well as to have some insulating value for protection against regain of moisture to the product under abnormally high humidity conditions and to help protect against freezing or extreme heat. Often the manufacturer overlooks the fact that the weather in his packing

room is the weather with which he actually surrounds his product when placed in one of these moisture-proof containers. It follows therefore that the control of this weather is essential if the whole theory of proper packing is to be made valid. For instance, product packed in a room having conditions of 85 F dry bulb and 60 percent relative humidity, which may easily be encountered in a normal summer, would have air surrounding the product at a 69 F dew-point. If this sealed package were then subjected to temperatures below 69 F, the air in the package would tend to become super-saturated and moisture would condense on the surfaces of the container and the product. If this product at a later time were then subjected to a higher temperature the moisture would re-evaporate, but in this process, if the product was chocolates, they would lose their lustre, and if marshmallows, a sticky or grained surface would result, depending on the formula used. Obviously then the control of the air conditions in the packing room is essential. In actual practice, conditions of 65 F dry bulb and 55 percent relative humidity have been found to be about the maximum practical. An improvement will be obtained if the relative humidity can be dropped several points. In the case of hard candy where this material is intensely hygroscopic, the relative humidity should be reduced to 35 or 45 percent at 60 to 65 F temperature.

Fig. 3. Typical Cold Diffuser Unit Suitable Various Applications in Candy Manufactur Processes.

Storage

Every manufacturer is anxious to have his products reach the ultimate consumer in the same fine quality that they leave his plant. If the products could be sold to the ultimate consumer immediately after finishing there would be no problem in this regard; however, it is usually necessary, particularly with seasonal items, to provide storage facilities in order to even out the production requirement on the factory. Therefore, it becomes necessary to air condition the storage spaces to insure the products remaining in prime condition. Generally speaking, it has been found that most types of finished goods will keep for a considerable length of time if stored in room conditions not to exceed 70 F dry bulb with 40 to 50 percent relative humidity. An exception to this is in the case the storage of nuts where the dry bulb te perature is normally held between 30 to F with 75 percent relative humidity. Th conditions prevent excessive dehydrat of the nuts while at the same time ret any mold growth and tend to keep any sect eggs dormant.

The conditioning of the storage roon a relatively easy matter, it being the us practice to use the unitary type equipm known as cold diffusers (see **Fig. 3**). Th are fan and coil units connected to external source of refrigeration. The nu ber and size used is determined by lo requirements and air distribution. Usua these units are fitted with directional fl outlets and no additional ductwork is n essary. The population load in these roo is very low so drafts ordinarily are objectionable, it only being necessary secure air supply to all parts of the roo

ı this connection, it is necessary to al-
›w sufficient space between the top of
ıe loaded product and the ceiling in order
› provide a plenum chamber for the dis-
ibution of the conditioned air. If prod-
ct is to be withdrawn during hot humid
ımmer conditions, it is generally wise to
rovide a tempering space directly adja-
ınt to the shipping dock where the goods
moved from storage can remain for about
4 hours before shipment. This space
ıould be maintained at about the out-
de dry bulb temperature and a rather
w relative humidity. This permits the
roduct to warm up to the outside tem-
erature without the danger of sweating.
his can be done by taking a small out-
de air quantity on one of the units han-
ing the storage room. This air would then
e relieved through the tempering space
› maintain the required conditions.

Refrigerant Plant

Most candy manufacturers employ a
ıntral refrigeration plant using centrifu-
ıl refrigeration for cooling water or high temperature brine. Ammonia was used in the past, and although it is satisfactory from an operating standpoint, the refrigerant is classed as hazardous and toxic, and it must be handled with care. For such uses as packing rooms, dipping rooms, etc., where the number of employees is large, it is important that ammonia not be directly expanded in a coil in the conditioned air path, since a leak at this point would rapidly flush ammonia throughout the entire packing room. Further, most city ordinances prohibit this practice where the population occupancy is more than one or two receiving or shipping workers. For this reason in using ammonia, it is recommended that the ammonia be confined to the machine room and a brine or water cooler be used. Chilled brine or water can then be safely circulated throughout the plant for the various requirements.

In some of the smaller modern plants Freon-12 refrigerating equipment **(Fig. 4)** has been utilized with excellent results. With this arrangement (since Freon-12 is classed as a safe refrigerant) the restriction

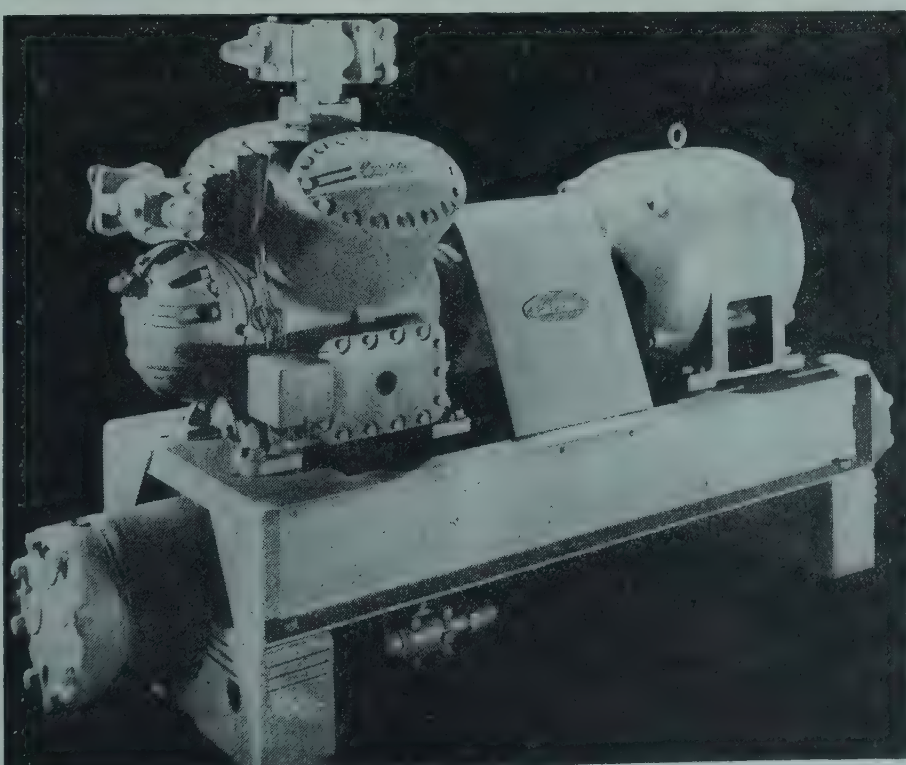

Fig. 4. Modern High Speed Reciprocating Condensing Unit.

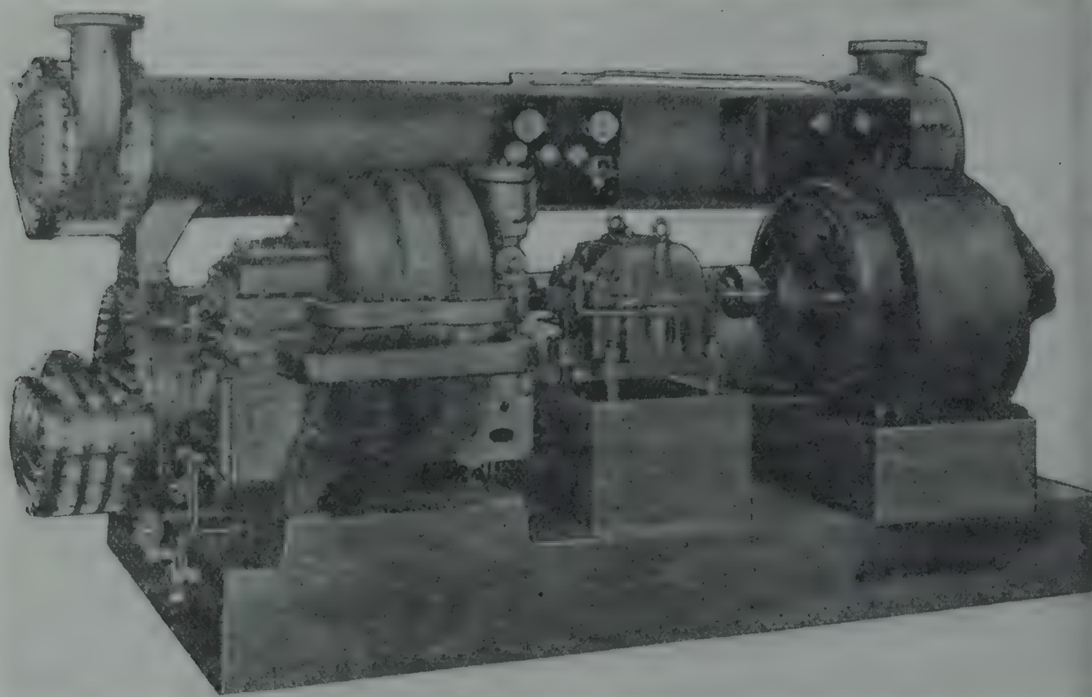

Fig. 5. Centrifugal Refrigeration Equipment Suitable for Chilling Brine for Use Throughout the Candy Plant.

of direct expansion is not necessary. Normally small units are used for each requirement or each group of requirements, thus one compressor may be installed on a cooling tunnel while separate compressors are used in each of the departments for packing, storing, etc. This arrangement permits a planned program of expansion or rehabilitation of a portion of the plant at a time and thus over a period of years, complete modernization of any plant can be accomplished. If the plant is rather large, this however results in a multiplicity of small units and adds considerably to the work of the operation and maintenance crew and therefore serious consideration must be given to the central system although the capital outlay may be large.

The difficulty of multiple units is eliminated through the use of a centrifugal machine as shown in **Fig. 5.** These machines use Freon-11 refrigerant, commercially known also as Carrene No. 2, and have been applied to the majority of large candy plants in this country. This equipment is applied very satisfactorily providing there is sufficient load to make its first cost feasible or if management is far sight enough to plan for future expansion. other words, if the load is in excess of 50 60 tons, the centrifugal may fit the pictu

A centrifugal machine consists of a co plete assembly of cooler, condenser, co pressor and drive, and can be located r motely in the engine room under dire supervision of the operating engine Brine piping can be extended througho the building and great flexibility can th be achieved. In addition, the centrifug machine can be driven by either motor turbine. In many instances the turbi drive proves very satisfactory since it c fit into the heat balance of the plant. M candy plants generate steam at high pr sure for use in various cooking operatio Turbines can be secured either to utili this high pressure steam, exhausting at back pressure for lower temperature coo ing operations, or can take exhaust stea to condensing, and thus can be made integral part of the heat balance of the e tire plant. The centrifugal has the adva tage of extreme reliability, low operati cost, ease of maintenance, and long life.

It has been the practice in the past to refrigerate brine to a temperature of 20 to 25 F for all services in the plant, and although this temperature is lower than that necessary for many of the operations the advantages gained by load factor balance and central plant operation have warranted its installation. In the past this temperature was necessary because of the design of the evaporators, which in many cases were prime surface coils in the storage and packing departments. Use of modern air conditioning units with fin type evaporators has eliminated the necessity of the low temperature brine. Experience has indicated that high temperature brine of 28 to 32 F is very desirable for central station installations. This brine temperature is sufficiently low to obtain the necessary low dewpoint temperatures for many of the processes, yet is high enough to prevent frosting on the fin evaporators. Solutions of alcohol and water or a weak solution of calcium chloride brine have been used in some plants, and it is entirely possible that some of the glycols can now be applied. Because of increased production the tendency is to lower brine temperatures particularly to cool air to a lower temperature supplied to tunnels.

The brine distribution system makes it possible to connect all of the varied services to one source of refrigeration and by the use of pneumatic control devices dry bulb temperatures and dewpoints can be maintained very accurately. Cold slabs for caramels, nougats, and other similar operations are supplied with this temperature brine, and its use is even extended to comfort cooling in the offices and various clerical operations. For the very large manufacturing plant it is a well established fact that the centrifugal refrigeration in single or multiple units will provide the best installation and most economical operating plant when all costs are considered.

For the smaller manufacturing plant the use of multiple Freon machines with direct expansion seems to be the best answer. As various departments are altered or expanded these can be cut off the old ammonia systems and replaced with individual air conditioning units and separate Freon compressors. For instance, a candy packing room can be very excellently air conditioned by one or more units with direct expansion fin coils and one or more Freon compressors. The Duplex Freon compressor has been used with excellent success for installations of this type. Similarly, cooling tunnels are equipped with separate cold diffusers and connected to individual Freon compressors or a group of units are connected to one single or duplex compressor. These compressors vary in size from 5 hp to about 50 hp and can be located adjacent to the spaces conditioned. A planned program of rehabilitation can be accomplished without shutdown and without the necessity of financing a single large project at any one time.

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If you searched this chapter for something which was not found in it, please let the editors know.

79. MAN-MADE TEXTILE FIBERS REQUIREMENTS FOR AIR CONDITIONING AND REFRIGERATION

THE natural fibers, principally wool, cotton, and silk, played a very large part in the development of our modern world but, being modern, the scientific part of that world has, for years, been fully aware of their shortcomings.

Each of these natural fibers ("Fiber: . . . In order to be spun into a yarn a fiber must possess sufficient length, strength, pliability and cohesiveness. . . ."[8]) has its own set of physical properties which makes it more suitable for one use than another—perfectly suitable for few, if any, uses. Each has its irregularities. Wool grows according to the severity of the winter. Cotton ripens sooner on the southern side of the hill but the whole crop is picked at the same time. The staple ("Staple: 1. A fiber of cotton, wool, flax and the like. 2. The length of such a fiber. . . . "[8]) varies in any one crop and from crop to crop.

To provide new fibers tailor-made to serve more specific purposes better and, at the same time, of controllable uniformity, man accepted the challenge and developed the art of manufacturing them from nature's raw materials.

L. LOGAN LEWIS, Author Chapter 79. Born 4/16/87, near Lexington, Kentucky. Educated at University of Kentucky, BME, 1907; ME, 1909. Formerly, Instructor, Univ. of Kentucky, 1908–09; Engineer, Carrier Air Cond. Co., 1909–15; One of seven organizers of Carrier Engrg. Corp., 1915; Chief, Application Engrg., Secretary, and Director, 1915–36; Vice President, Carrier Corp., 1936 to date.

Author of a considerable number of articles in various publications on "Air Cond. in the Theater"; "Methods of Air Distribution"; "Possibilities of Conditioning for Comfort"; "Provisions for Public Safety in Air Conditioning"; "Modern Air Conditioning—What it Means to the Water Utility"; "Moisture Removal from Blast Furnace Air"; "Humidity as a Factor in Food Storage"; "Rayon Manufacture." Co-author "Air Cond. the Halls of Congress"; "Why Dry Blast is Different Now." Author Chapter 74, 1946 Applications Volume, ASRE Data Books.

Fellow, Amer. Soc. of Refrig. Engrs.; President, 1940; Chairman, New York Section. Member, Amer. Soc. of Heating and Vent. Engrs.; Technology Club, Syracuse, N. Y.; sub-committee on armoured vehicles, National Research Council, 1942–45.

At present, Vice President, Carrier Corp., Syracuse, N. Y.

What has been accomplished, is well illustrated by the criteria by which suitability is judged. For one example, du Pont[1] gives data on nylon for such chemical-physical properties as abrasion resistance, chemical resistance, density, elastic recovery, electrical properties, extractable matter,—resistance to light, heat, insects, mildew, mold, and fungus—inflammability, moisture regain, shrinkage, swelling, stretchability, modulus of elasticity, tensile strength, elongation and toxicological properties. For another, Textile World's Synthetic Fiber Chart[2] tabulates twenty properties for ten different fibers.

Most, if not all, of the processes by which such fibers are manufactured require air conditioning or refrigeration or both—and obviously, the focal point of the engineer's interest lies in their requirements for his products. To serve his interests well, it is also obvious that, if nothing else, approximate data on such requirements should be given. But unfortunately, the reader must be forewarned that such data are not to be found herein.

The reasons for their omission, however, are quite pertinent. The number of basic types which are being manufactured is considerable. Deviations in chemistry or process modify the physical properties of one basic type, producing either a tire cord or a lingerie yarn. Production comes from a small number of plants owned by a considerably smaller number of large organizations (listed in 2). Most, if not all of these organizations have their own engineering departments charged with various responsibilities, including that of guarding their competitive advantages.

* * *

There are many more ways of making a silk purse than "out of a sow's ear." Apparently almost anything which can be forced through a spinneret **(Fig. 1)** or attenuated and then solidified by chemical reaction, or by the evaporation of a solvent, or by cool-

ing, can be manufactured into a fiber—and eventually put into one of the many forms suitable for the manufacture of textile articles. Even glass and metals are not excepted.

Fig. 2 provides a comprehensive list which, incidentally, makes it obvious that even to outline the basic processes by which each is made, is beyond the limitations of available space. For the details of such, the reader is referred to "The New Fibers,"[3] Chem. and Met's Flow Sheets,[4] various publications by Textile Book Publishers, Inc.,[5] and semi-technical booklets which may be obtained from most of the manufacturers (listed in 2).

Outlining the air conditioning and refrigeration requirements of the entire lot is, likewise, beyond practical limits, but can be summarized in principle and well illustrated with two examples. The general principles which apply are:

1. **Controlling the rates and limits of chemical reactions** by controlling temperature. For smooth flow, each batch must be ready at the right time—to avoid loss of time or loss of quality.
2. **Protecting the worker from toxic or obnoxious by-products** by collection at the point of origin, or by dilution with ventilation, or both.[6]
3. **Improving the efficiency and welfare of the worker** by absorbing the excesses of heat that may be generated by the process. In some instances, heat may also be collected at the point of origin and removed by exhaust.
4. **Stabilizing, at the most favorable point, those physical properties of the fibers** which are influenced by temperature and humidity. This may include even such as glass fibers, the tensile strength of which is greatly reduced by the adsorption of water vapor.[3]
5. **Protecting the product from air-borne dirt and sweaty hands.**
6. **Controlling the final moisture content of products** which are sold by the pound and, are of greater value to the purchaser when shipped with the stipulated moisture content.

For illustrative purposes, the processes

Industrial Rayon Cor

Fig. 1. Spinneret.

The "liquid" becomes a solid again. The visco is forced through the almost invisible holes of thimble-like spinneret into a chemical solutio called a spin bath. As the viscose comes into co tact with this spin bath, it solidifies instantly int filaments of rayon yarn.

of manufacturing viscose and acetate rayon are the best for various reason Viscose was the first to be developed com mercially—and naively termed artifici silk. More is known about both of the than of other man-made textile fiber They account for a greater tonnage tha any others, 1948's production amountin to more than a billion pounds.[7]

The two processes are radically differen Making viscose rayon may be popular defined as the regeneration of cellulose. is done by a chemical-textile process which the cellulose is first converted into liquid phase, and then resolidified in th form of filament. The final product is th result of a chemical reaction in the spi bath. Acetate is an ester of cellulose—sp cifically cellulose acetate. In making it, chemically prepared substance is dissolve

* These two fiber types are both called "rayon" unde ruling of the Federal Trade Commission, but the Ame can Society for Testing Materials has recommended t use of the more distinctive words "rayon" for viscose a "estron" for acetate.

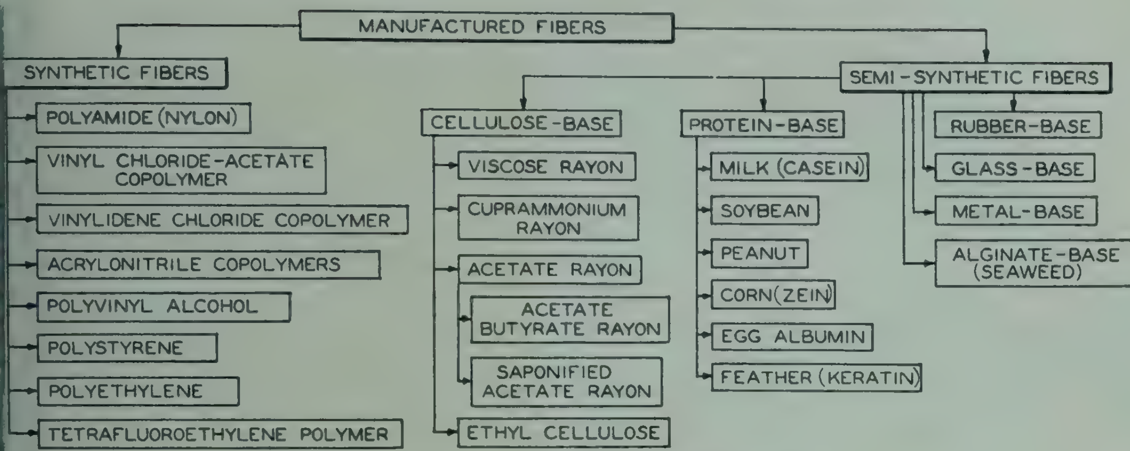


Fig. 2. Classification of Manufactured Fibers.

in a solvent and then resolidified by the evaporation of the solvent—in filament form.

The final products are turned out in two general forms—in continuous filaments miles in length and in staple, cut to exact lengths ranging from 1 to 7 inches. The number of filaments formed in parallel may vary from mono-filament up to almost 3000. The individual filament may be exceedingly fine (more than 2500 miles to the pound) or relatively coarse.

If a single bundle contains less than some 200 filaments it is given just enough twist to hold it firmly together, is known as yarn and is ready for the twisting (or throwing) processes originally developed for natural silk. If the bundle consists of about 1500 or more it may be shipped either in a loose, rope-like form known as tow, or it may be cut into staple, baled like cotton—ready to be spun on the cotton system.*

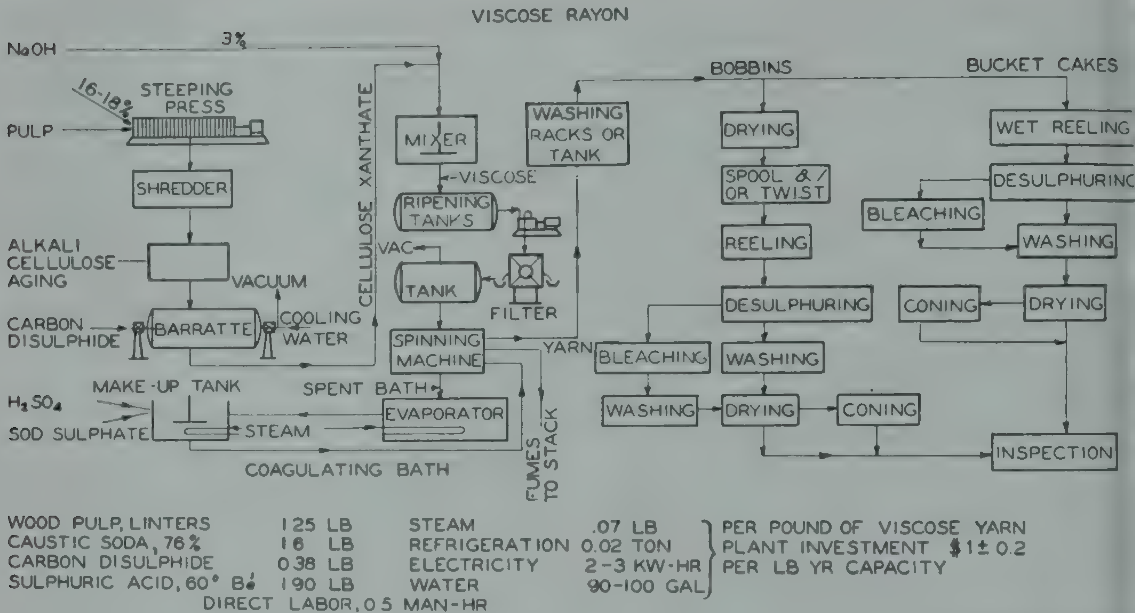
Manufacture of Viscose Rayon

The "Flow-Chart" in **Fig. 3** outlines the process; **Fig. 4** pictures it. The requisite raw materials consist primarily of cellulose and certain chemicals. While cotton linters may be used, most of the cellulose comes in the form of a specially prepared spruce pulp, in sheets approximately $30 \times 30 \times \frac{1}{8}$ inches, carefully packaged, and having the general appearance of coarse blotting paper. Shipments are received in bulk, and promptly put in storage where they may be held for considerable periods.

Storage: Although the pulp is quite hygroscopic, adequate heating meets storage requirements satisfactorily. But, it is to be noted, that depending largely upon the season of the year, and other storage conditions, the moisture content of the pulp may vary as much as four or five pounds per hundred pounds of dry pulp. Unless offset by some other means, such variations will alter the strength of the caustic solution used in the first step of process. Preconditioning the pulp and holding it in a conditioned storage would eliminate this variable, but the presumption is that the cost of such conditioning would be greater than its benefits. This point is made primarily because raw materials for other fibers may require preconditioning.

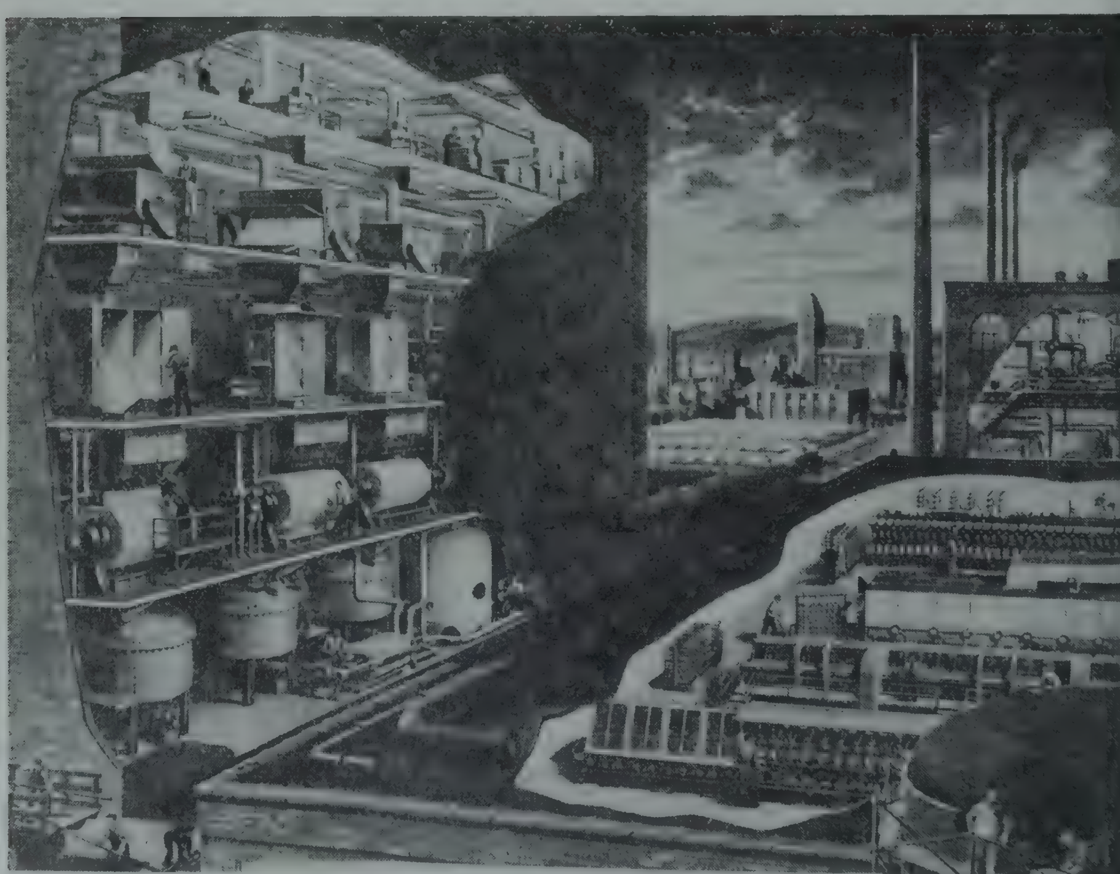
Steeping: As they are removed from storage, the sheets of wood pulp are taken from various shipments, blended for greater uniformity, and then divided into batches of predetermined weight. The sheets from each batch are then placed on edge in long vats **(Fig. 5)** and steeped for about two hours in a solution of caustic soda. The caustic removes impurities and combines with the cellulose to form an alkali of cellulose—specifically sodium cellulose. When the reaction has progressed sufficiently, the excess solution is drained off and most of the remainder pressed out with a hydraulic ram.

* In the textile mill, spinning (generally cotton or wool system) is the process of drafting or attenuating small ropes of parallel staple fibers—and applying twist in a single operation. The throwing mill processes continuous filaments to which it applies twist—but obviously no draft. The throwster, however, uses one machine which he calls a spinning frame.



Chemical Engineering

Fig. 3. Viscose Rayon "Flow Sheet."



Armstrong Cork Co.

Fig. 4. Cut-away View of a Painting Showing How a Rayon Plant Operates.

On left top to bottom—steeping, shredding, aging, xanthating, and ripening. On right front to rear—spinning on through to ready-to-ship packages.

Shredding: The soft, damp sheets then go to the shredders, in which they are torn and beaten into fine flocks or crumbs **(Fig. 6).** In the shredder, heat is generated by the power used in driving it and by the mild reaction which continues. All of this heat must be absorbed, and the mass held down to a predetermined temperature.

For this purpose, the shredder is constructed with a jacket through which a refrigerated fluid is circulated. Depending upon the relation of cooling surface to the rate at which the shredder is operated and the size of the batch—this cooling may be done either with 38 F water or with brine at 10 to 15 F. In some instances, jacket cooling may be supplemented with chilled air blown into the shredder. Both the prime and the supplementary requirements are determined largely by the design of the shredder, and the practice in the plant in question.

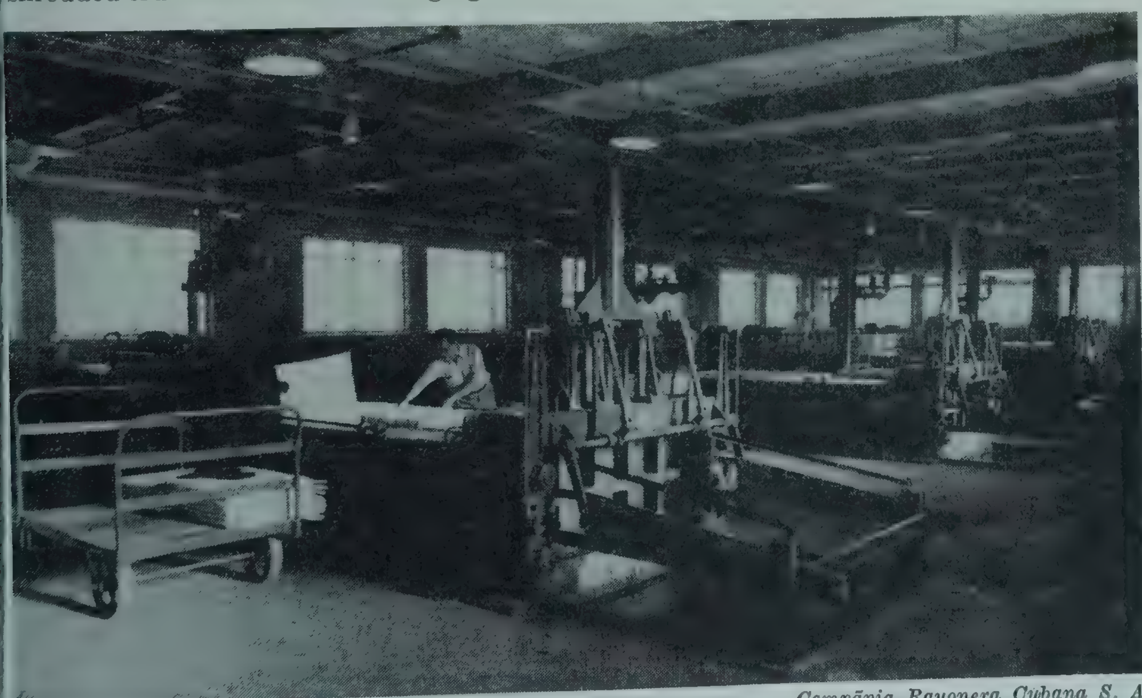
No toxic gases or particles are given off, and most of the heat generated by power is absorbed through the jacket. Supplementary air cooling, however, has the advantage of doing by-product cooling in the shredder room.

Aging: Packed in metal containers, the shredded crumbs are held in the aging room for a period varying from 47 to 72 hr. The process is one of mild chemical reaction and equalization. Some heat is generated but is insignificant in amount.

Since the rate of chemical reactions in general is a direct function of temperature, (doubling approximately for each 20 F rise in temperature), it is essential to control the temperature of the aging room. Narrow limits are important because otherwise the eventual spinning characteristics of the viscose solution will be adversely affected. Variations beyond certain limits may result in an unsalvageable batch. The objective is a precise time-control of a chemical reaction.

Since the crumbs are aged in metal containers, the prime requirement is that of holding the room down to a temperature level prescribed by chemical requirements —usually between 60 and 70 F. Relative humidity is not a factor. Uniformity of temperature and accuracy of control are of high importance and to facilitate both, the aging room should be exceptionally well insulated. Uniformity of air movement is also important because impinging drafts will alter the rate of heat transfer from the surface of the container.

Xanthating: When aged to the right de-



Compãnia Rayonera Cubana S. A.

Fig. 5. Steeping.

The first step in the preparation of viscose is performed in hydraulic, end-opening steeping presses on the fifth floor of the chemical building. Press charges range from 500 to 550 pounds of air dry pulp.

gree, the crumbs are placed in revolving churns **(Fig. 7)** and treated with liquid carbon bisulfide. The result is an orange-colored crumb known as cellulose xanthate. Heat, together with toxic and explosive gases, are generated within the churn, which is tightly closed.

Since the xanthating reaction must be kept under control, and stopped within closely prescribed limits, the heat must be absorbed by circulating either refrigerated water or brine through the jacket of the churn—supplemented in rare instances with chilled air. As in shredding, the requirements are determined by the design of the shredder and the practice of the plant. As to the gases, provision must be made for venting the churn and thoroughly flushing it out before it is opened.

E. I. du Pont de Nemours

Fig. 6. Shredding.
Soft damp sheets of cellulose are put in the shredding machine where they are torn and beaten into fine shreds.

The design objective is that of holding room temperature at 75 to 80 F and keeping toxicity within prescribed limits—generally about 10 parts per million.[6] A supply of all outside air at the rate of about twenty changes per hour is good practice. Humidity is of no particular significance except as it affects the worker.

After xanthating, the crumbs go to the vissolver, in which they are treated with a weak caustic solution (sodium hydroxide), and where rapidly revolving blades beat the mass into uniformity. The reaction converts the crumbs into a fluid, having the general appearance and viscosity of molasses—the source of the name "viscose." It is also exothermic, and the heat which is generated must be absorbed by jacket water.

Ripening: The resulting fluid then goes to closed tanks in the viscose cellar (Fig. 4), for de-aeration and ripening. A mild chemical reaction continues and a small amount of heat is generated.

Since a variation of only several degrees will make as much as a ten-hour change in ripening time, uniformity of temperature and air distribution is of great importance. Temperature level is fixed at some point between 60 and 70 F by the chemistry of the particular process.

Spinning:* In the spinning frame, the ripened, thoroughly filtered viscose spinning solution is pumped through spinnerets (Fig. 1) which are submerged in a bath **(Fig. 8),** the main constituents of which are

* Not to be confused with other confusing textile terminology. In spinning cotton, approximately parallel short fibers are attenuated (drafted) and twisted in one step. In throwing, continuous filaments are twisted—obviously cannot be drafted. One step in throwing, however, is called spinning.

ilute sulfuric acid and sodium sulphate—eated to about 100 F. The strongly alkane viscose solution is neutralized by conact with acid and converted into filaments f regenerated cellulose.

The spin-bath reaction generates considerable quantities of hydrogen sulfide nd carbon bisulfide, together with traces f sulfur dioxide. In addition, fine droplets f acid are thrown about by rapidly movng parts of the spinning frame **(Fig. 9).** Some of these by-products are eye-irritants nd others are toxic—and obviously the workers must be protected from them.

The American Standards Association's Standards Z37.2 and Z37.3, set "the maximum allowable concentration of hydrogen ulfide," and carbon bisulfide respectively, at "twenty parts per million parts of air by volume for exposure not exceeding a total of eight hours daily." Brandt[6] recommends that sulfur dioxide be held at ten parts per million—generally accepted as desirable practice for all three. This is accomplished by a combination of collection at the source by means of exhaust and dilution by means of supply (Fig. 8).

* * *

The major functions of air conditioning are, first to safeguard health, second to match exhaust with supply, and third to maintain relative humidity within close limits—temperature within somewhat wider limits. In general, relative humidity must be held above a minimum of 70 percent, but either product or process may dictate the need for a higher one. If humidity is deficient, excessive evaporation will cause crystals to form on the filaments—salting the yarn.

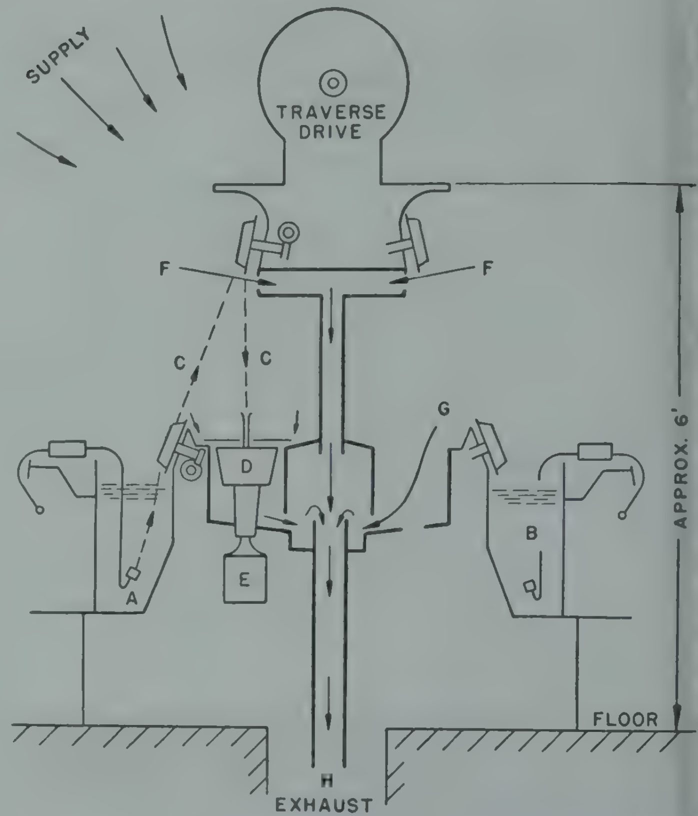
Normally the spinning room is heated to

E. I. du Pont de Nemours

Fig. 7. Xanthating.

After aging, the shreds are thoroughly mixed with liquid carbon bisulfide in a revolving churn to form xanthate.

75 F throughout the winter and cooled by means of evaporative cooling during the summer. In a few plants, however, refrigeration has been applied—holding the top dry bulb down to about 85 F. The resulting environment is more conducive to better worker efficiency and the lesser day-to-day fluctuations in dry bulb smooth out certain irregularities in operation. This can be viewed from opposite angles—getting regular service out of a process-refrigeration emergency machine—or as having a regular for spinning which can be made available for a process-refrigeration emergency.



H. W. Butterworth and Sons C

Fig. 8. Partial Cross-Section of a Viscose Spinning Frame.

a. Spinneret, b. Spin bath, c. Travel of yarn, d. and e. Po and motor respectively, f. Upper exhaust ports, g. Lower exhaus ports, h. Connection to exhaust system.

Spinning Room Supply System: The amount of air, which obviously must be all outside air, and the amount of refrigeration to cool it, are influenced by many factors which, in turn, are determined by the type and design of the spinning frame—of which there are three, bobbin, pot, and continuous. The bobbin machine extrudes and coagulates the spinning solution, without applying twist. Pot spinning applies twist and, since the pots revolve at exceedingly high speeds (5000 to 10,000 rpm), creates more turbulence and throws more acid. The continuous spinning machine **(Fig. 10)** performs all of these operations (Fig. 3) from spinning on through drying, and, with amazing ingenuity, compresses the start-to-finish time down into about 6 minutes—from an otherwise 90 hours.

More or less air will be required according to the design of the spinning frames. Some frames are enclosed (note the glass sash in the machine in central foreground of Fig. 4) and the exhaust can be cut by more than a third. Others are wide open (Fig. 9). The economics of enclosure are not clean-cut one way or the other. Almost all metals which are otherwise suitable for hinges, latches, rollers, etc. are violently attacked by the ever-present acid. The enclosure makes access more difficult and more time-consuming. The right humidity must be maintained, both in the spinning room and within the enclosure. More or less air is required according to the denier,* the number of filaments and other characteristics of yarn or process. Very roughly, the range is from 25 cfm per spindle (or spinneret) with enclosure up to 125 cfm without.

Probably the most important consideration of all in the design of the supply system is a balance between uniformity of distribution and freedom from turbulence. Any drafts of sufficient strength to pull toxic by-products out into the breathing

* "The denierage of a yarn is the weight in grams of a length of 9,000 meters of a yarn," A.S.T.M., D258-44. In multi-filament yarn denier applies to the bundle of filaments. High deniers indicate relative coarseness, although each individual filament may be very fine.

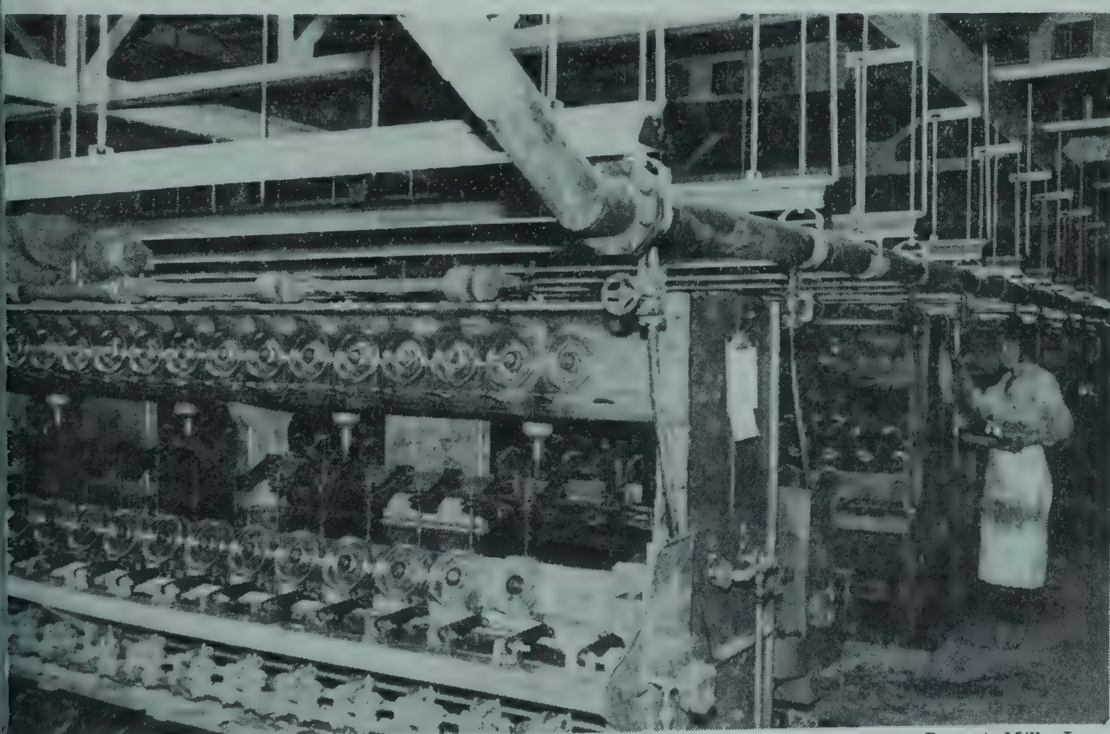
ne, either increase the requisite capture-elocity of exhaust or defeat one of the ime purposes of the system. For pot spinng frames a goodly number of pan-outlets ill give good results. Perforated ceiling stribution is better, provided it is adeiately protected from acid fumes.

Spinning Room Exhaust: The volume of r to be exhausted depends in large meas-e upon the volume to be supplied and, in ldition, upon the same factors which dermine the latter. The points from which is taken and the size and location of the orts are determined largely by the design the spinning frame, the body of which rms a partly defined plenum chamber 'ig. 8).

These plenums are connected to a sysm of underground ducts leading to an chaust fan—discharging into a tall stack. he stack elevates the point of discharge ifficiently to hold the ground-level dilu-on of odors and fumes, below the point of ublic nuisance. Some of the tallest of nese stacks are more than 300 ft in height; some of the largest, more than 25 ft in diameter.

Lead is the most acceptable material for the plenum chambers and the smallest parts of the duct system. Concrete lined with acid resistant brick or tile is generally used for the larger runs; brick for the stack. Exhaust fans (axial flow is the best) may be constructed of various materials and protected in various ways. Among them are concrete housings, rubber coating and various types of paint and plaster. Practice varies over a wide range according to individual preference and practical experience with rayon plants.

Transition—Chemical to Textile: Up to and including spinning, practically every part of the plant, must operate 24 hrs per day, seven days per week. Beyond spinning the process changes from one of preponderantly chemical to one of textile character. The product at this point, is a regenerated cellulose in lengthy continuous filaments thoroughly contaminated with spin-bath residue. The next steps are aging



Beaunit Mills, Inc.

Fig. 9. Spinning.

In the spinning room, viscose is forced through a spinneret into acid bath, changing the liquid to silky thread.

Industrial Rayo

Fig. 10. Continuous Machine Spinning, Washing, Desulfurizing, Bleaching, Drying, Twisting, and Winding Rayon Yarn on Bobbins.

The flow of yarn is from top to bottom.

to get rid of green fibers, freeing the product from acid, bleaching it, and putting it in one of the dozens of marketable forms—or in textile terms, packages.* Here again variations in practices are wide (Fig. 3) depending largely, but by no means entirely upon whether the product is tow, staple, or yarn. The cake which is made in pot spinning will be used for illustrative purposes.

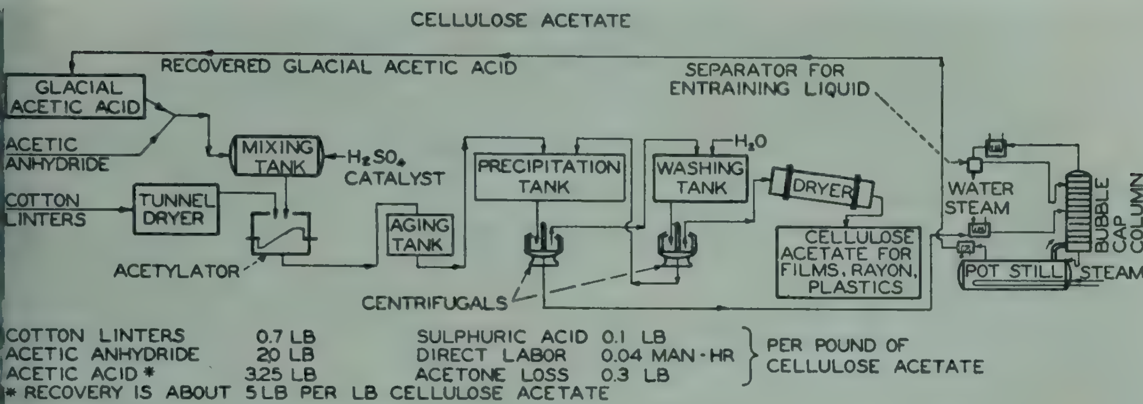
Cake Aging and Storage is the reservoir between the continuous and the intermittent parts of the process. The cake is a cylindrical package of yarn about 7½ in. OD, 5½ in. ID×5 in. Since it is saturated with acid, evaporation must be reduced to a point at which salting will not occur. This can be satisfactorily accomplished at a temperature of about 85 F and a condition approaching fog or super-saturation. Heads, atomizing water by means of compressed air or impact, give the best results.

* Package: A broad term for any ball, spool or other convenient form into which a textile yarn is wound. A quill will weigh only a few ounces; a beam, may approach a ton.

Lacing or Wet Reeling are alternat processes of preparation for succeedin steps. The first is that of lacing the cake i such a way as to keep the yarn from tan gling and then placing it in a bag—i which it is processed and may eventuall be shipped to the purchaser. The second i the largely supplanted process of wet reel ing or putting the yarn in the form of properly laced skein or hank—requiring minimum of 70 and preferably about 8 percent relative humidity.

Washing, Desulphurizing, Bleaching etc. are finishing processes, the primary re quirements of which are generally satisfie by ventilation—considered beyond th scope of this chapter.

Drying and Conditioning: In this ste the excess water is removed from the clea yarn and its final regain fixed. Severa types of continuous conveyor-belt an truck driers, suitable for either cakes o skeins, have been developed, refined as specialty, and are commercially availabl



Chemical Engineering

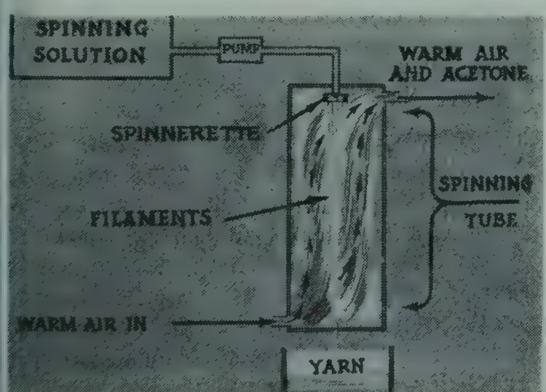
Fig. 11. Cellulose Acetate or Estron "Flow Sheet."

For description of acetic acid recovery system shown, see Othmer, *Chem. & Met.*, Dec. 1933.

The air conditioning engineer's interest is generally limited to the conditioning section.

This section serves two purposes. It cools the dried material close to the temperature maintained in the room at the delivery end of the drier, and thereby prevents flash-off or sudden loss of regain. It puts the desired final moisture content (10 to 11 percent for viscose) in the product. This can be done with direct water sprays but the best results are obtained with a spray washer system, the size of which had best be left to practical experience with the type of drier and the type of product in question.

Inspecting, Grading, Sorting: These processes require a clean atmosphere and hands that are free from perspiration plus a relative humidity of 58 percent to maintain the proper regain. The prime purpose served by refrigeration is the maintenance of an effective temperature under which perspiration will be reduced to a practical minimum. In general, a dry bulb of 80 F is satisfactory. Such conditions will not completely eliminate perspiration but are practical if prone-to-perspiration workers are culled out.



American Viscose Corp.

Fig. 12. Liquid Spinning Dope is Drawn from the Spinning Tanks and is Forced through the Spinnerets Vertically Downward into a Hollow Tube through which Warm Air is Passing.

Warping, Winding, Quilling, etc. are textile mill processes. Information about them may be obtained from the chapter on Industrial Air Conditioning or from the textile references which have been cited.

Manufacture of Acetate Rayon

Unlike viscose, acetate or estron is an ester of cellulose—specifically an acetate of cellulose. The process of making it is generally termed dry spinning in contrast with the wet spinning of viscose. The basic difference is that the cellulose is first put in its final chemical form **(Fig. 11)** and the spinning solution then prepared by dissolving it in acetone. Coagulation is obtained by evaporating the acetone with a stream of conditioned air, thereby producing a product ready for winding, warping or quilling without further treatment. The spinneret is placed at the upper end of a vertical tube **(Fig. 12)** through which spinning room air is exhausted—counter-flow.

Currently, practically all, if not all, acetate rayon is made from cotton linters (but a recently developed process for suitably preparing wood pulp points toward the possibility of change). The linters are first treated with an acetic acid anhydride, gla-

American Viscose Corp.

Fig. 13. Acetate Spinning Room.

cial acetic acid, and a catalyst (usually sulfuric acid), to form the cellulose acetate. The acetylating tanks for this are jacketed for the circulation of a refrigerated fluid to control the temperature of the reaction—close control being essential for uniformity of viscosity, acetic content, etc. The amount of refrigeration required must be had from practical experience with the particular type of equipment involved.

The tri-acetate thus formed is then hydrolyzed until a desired di-acetate is obtained. Then by admixture with water, the acetate of cellulose is precipitated in the form of a white flocculent mass. After a thorough washing and drying, the flocs are dissolved in acetone to form the spinning solution or dope.

The air conditioning problems presented by the preliminary steps of this process are of the same general character as those for viscose. In the preparation of the spinning solution the rates and limits of chemical reactions must be controlled by holding temperatures within predetermined units. Toxic, explosive, or otherwise objectionable gases must be collected and limits of concentration kept below the point of industrial hazard. In these preparatory steps the relative humidity is either of secondary importance or of none at all and ventilation will usually suffice.

Spinning: As in viscose, the principal requirements for air conditioning and refrigeration are to be found in the spinning room **(Fig. 13).** The broad features of design are identical—supply and exhaust, but the requisite atmospheric conditions are determined by vividly contrasting (and pertinently illustrative) factors. In making acetate, the solvent must be evaporated at a pre-determined speed—must not be retarded. Solvent vapors must be diluted below an explosive mixture and recovered. The dew point of air must be safely above the wet bulb temperature of the solvent or else water vapor will be condensed by the evaporation of the solvent.

Conditions of 95 F and 20 to 30 percent are generally satisfactory. The 95 F must be carried year-round in order to give a constant drying rate for the solvent—and

o maintain the production schedule. As in iscose, shutdowns are costly, making 24 r days and 7 day weeks the rule.

Supply System: The air volume must be ufficient to take care of the spinning room oad and a sufficient part of it must be aken from outside to match the exhaust nd to hold the concentration of acetone apor down to an acceptable level. Brandt[6] ecommends 500 parts per million but in ractice, 1500 appears to be entirely ac-eptable.

This points toward a seasonal compro-nise between initial investment and re-ults. Obviously the refrigerating machine nust have sufficient capacity to hold ace-one down to 1500 parts per million when he outside wet bulb is at its maximum. But since the refrigerating load is largely lependent upon outside wet bulb, the por-ion of air taken from outside can be in-reased as the outside wet bulb moderates. With suitable controls the mid-winter eating load can be dealt with in the same nanner. Such an operating practice will rovide the higher standard during a large art of the year at a relatively low increase n operating cost.

Exhaust System: The three prime requi-ites of exhaust are solvent removal, col-ection, and recovery. The solvent vehicle n which a pound of yarn is carried, is vorth much more than the yarn and, herefore, recovery is an economic must. The tubes or compartments in which the pinnerets are located, are connected to a eader built into the spinning frame. Ducts onnect the headers to the exhaust fan and hence to the solvent recovery plant which s generally activated carbon. Such a plant resents a definite fire hazard, to be dealt vith by experts in that particular field, but ts over-all performance and economics are enerally satisfactory.

Fibers in General

As in the case of viscose, the requisite olume of both supply and exhaust for ace-ate are dependent upon the fineness or the oarseness of the yarn, the design of the nachine and the practice of the plant. Supply and exhaust are effective, each in ts own way in preventing health or other azards, but are inter-dependent. Exhaust may be reduced in various ways but a re-duction of exhaust may bring the necessity of increasing supply. In addition supply must always be sufficient to maintain the requisite temperature and humidity in the space surrounding the machine, as well as at critical points within the machine where the fiber is exposed. One essential check on the sufficiency of supply is a reliable calcu-lation of load.

Accurate load calculations are essential in all new ventures with old fibers but trial-and-error experience carried on through the design and operation of successive pro-duction plants, provides the practical ex-perience which is essential to complete success.

In cases of new ventures with new fibers, experience factors are invariably developed in the pilot plant and then applied at full scale on the first production plant. The first production plant may then become the first one of several successive stages of modification and refinement.

With the exception of plants producing fibers from metals, glass, and some plastic materials, the air conditioning problem centers upon the chemical reaction in a spin bath or the evaporation of a solvent. In the exceptions, however, the same six principles can be successfully applied—provided excesses of heat, either sensible or latent, or both are gathered under the broad concept of air contaminants and, as such, industrial hazards.

In most of the continuous steps of proc-ess, cleaning up after a shutdown and re-starting are so costly as to become major misfortunes. Hence there is great need for all air conditioning and refrigerating equip-ment to be reliable and to be installed in such a manner that access and mainte-nance are easy. This applies perhaps with even greater force to good, simply con-ceived automatic control systems, for the best engineering and the best equipment approaches worthlessness if the controls do not function properly.

Summary

Currently, a wide variety of textile fibers, more suitable for various textile products than the natural ones, are being manufactured in large volume. In the fu-

ture both variety and volume are expected to increase.

Most, if not all, of the processes by which they are manufactured require more or less air conditioning and refrigeration—but are too various to be covered specifically—within the limits of this chapter.

Their requirements for air conditioning and refrigeration, however, are reduced to six basic principles and the application thereof, illustrated with a specific description of the manufacture of rayon, to give a perspective of the problems involved and alert the engineer to them.

This is not to be confused with textile processing. To the contrary it applies to the actual production of a fiber that is shipped to the textile mill to be spun, woven, or knitted by the textile mill in the same manner as cotton, wool, or silk.

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If you searched this chapter for something which was not found in it, please let the editors know.

80. LIBRARIES AND MUSEUMS

RESERVATION of priceless art objects and written records of civilization ould be acknowledged as a public trust. ompetent research has disclosed that the ain deteriorative agents are: Light, abrave dust, acidic pollution of the air, adrse temperature and humidity condins, and to some extent the impurities in e paper or other materials themselves. urators and librarians of institutions now uipped with properly applied air condioning are uniformly in agreement as to s benefits. Therefore, inasmuch as conolled atmospheric conditions may be jusfied on the basis of economics as well as ntiment, it appears likely that more conderation will be given to this mechanical ature for museums and libraries not alady equipped.

Research Work Accomplished

Tests conducted by Sir William Abney d reported to the British Association of efrigeration[1] by J. Macintyre led to the ntrol of light in galleries to cut out the traviolet, known to fade pigments. Also uring the course of these experiments, it as discovered that water vapor is a factor r more important than light in the deteriation of paintings. Recommendations as to conditions (57 to 63 percent, and 57 to 63 F year around) do not check with American practice, but consideration should be given to the prevailing weather in England where the tests were run.

As early as 1929 the American Library Association determined that factual data on the deterioration of records were necessary. Funds were supplied by the Carnegie Foundation, supplemented by Federal Appropriation, to support fellowships at the National Bureau of Standards. Starting with a survey of a number of important libraries, those conducting the study found that, in general, inadequate means, or no means at all, were employed to control the temperature and humidity of air in libraries, or to purify the air. There were indications that record material had deteriorated because of both extreme dryness and extreme wetness and that the general condition of material stored in congested areas was poorer than that of materials stored in areas where little pollution of the air was evident.

When the study had progressed far enough in generalities, actual installation tests were conducted at the Folger Shakespearean Library, Washington, D. C. An air conditioning manufacturer and a supplier of water-treating chemicals cooperated in the tests.

Results were published in a series of reports, two of which are shown in the bibliography.[2,3] Recommended conditions to be maintained are: 40 to 50 percent rh, temperature of about 80 F during hot weather and 70 F during cold weather.

Summary of Advantages

Books and Documents

1. Eliminates particles of abrasive dust, which:
   a. Have a detrimental action on paper and bindings of stored documents

REALTO E. CHERNE, Author Chapter 80. Born 12/10/07 in Duluth, Minnesota. Educated at University of Minnesota, BME, 1929. Formerly, Student Engr., Junior Engr., Senior Engr., Carrier Corp.; Chief Engineer, Carrier Australasis, Ltd., Sydney, Australia; District Chief Engineer, Syracuse, N.Y.; Branch Mgr., Cincinnati, Ohio; Director of Sales, Applied Air Conditioning, Syracuse, N. Y.; General consulting practice in mechanical and electrical engrg. 1945 to date.

Co-author "Modern Air Cond., Heating and Ventilating"; contributor to ASHVE Guide; ASRE abstractor; author of about 50 articles published in various technical magazines.

Member, Amer. Soc. of Refrig. Engrs., Secretary, Central N. Y. Section, 1940–41; Chairman, Cincinnati Section, 1944; on several national committees; Member, Amer. Soc. of Heat. and Vent. Engrs., Treasurer, Central N. Y. Chapter, 1945; registered professional engineer in New York and Minnesota.

At present, Consulting Engineer, Rochester, N. Y.

b. Act as nuclei for the condensation of moisture (sometimes acidic).

2. Retards **discoloration** of paper, parchment, textiles, and leather.
3. Maintains proper **air motion** and proper relative humidity which:
   a. Retards "brittling" caused by the air being too dry
   b. Eliminates brown blotches, known as "foxing," found on papers stored in damp places
   c. Tends to prevent paper from becoming soft and "fuzzy" as result of dampness
   d. Reduces the prevalence of molds, fungus, and mildew found in damp places with inadequate air motion*
   e. Materially lengthens the life of the adhesive or plastic bookbinding material
   f. Reduces susceptibility to decay of paper, cloth, thread, adhesives, and leather from chemical changes stimulated by adverse humidities (and, in some cases, temperatures).
4. Eliminates damage due to **sulfur dioxide** (provided water in air washer is properly chemically treated).
5. Prevents precipitation of **moisture** on stored materials by sudden changes in temperature during humid weather.

Paintings

1. Lengthens interval of time between necessary "restorations" of paintings. Such **restorations** are undesirable because:
   a. They are costly and require highly skilled artists
   b. They may impair the subtle quality and tone brilliancy imparted to the original by the artist
   c. They undoubtedly shorten the life of the painting. Some au thorities say that repeated re torations will render the pain ing worthless. (Methods of re torations were related in th November, 1937, issue of *Fo tune* magazine.)
2. Increases the life of paintings throug stabilization of moisture content i the canvas, thus avoiding harmf drying and wetting occasioned b continual changes in temperature ar relative humidity.
3. Reduces expensive maintenance ar rehabilitation of paintings made ne essary by appearance of "bubbles" "blisters" in the paint. These separ tions of paint from canvas are a tributed to frequent and wide fluct ations in temperature and relati humidity.
4. Greatly reduces, by means of ad quate air-cleaning devices, th amount of fine soot—which becom evident by streaks along borders paintings or etchings under glass.

Tapestries, Rugs, and Fabrics

1. Lengthens interval of time betwe necessary **cleanings,** which:
   a. Are costly and require high de gree of skill. Some curators a inclined to send them abroad f cleaning and restoration.
   b. Impair the brilliancy and ton
   c. Result, upon repetition, in we and damage.
2. Eliminates harmful and abrasi dusts from the air.
3. Guards against mold or mildew.
4. Lengthens the life by minimizing th "brittling" of fibre through chang in moisture content.
5. Eliminates sulfur dioxide from th air.

Antique Furniture and Woodwork

1. Eliminates usual winter-seas **shrinkage** which results in:
   a. Loosening of joints
   b. Exposure of unfinished stri along edges
   c. Tendency to twist or warp.
2. Prevents summer-season excessi

* Mildew is caused by a variety of vegetable organisms which propagate by means of spores nearly always present in the air. They grow very slowly below 40 F, very rapidly at the optimum temperature, which varies with the species; they are killed by elevated temperature. They require an abundance of water for growth. If the *relative humidity* is kept below 80 percent, paper, cotton, and leather will not contain enough moisture for the growth of mildew but glue and starch will. The latter can be protected, however, by use of a bactericide, such as betanapthol.

moisture regain, which:
  a. Promotes buckling or bulging of panels
  b. Causes splitting of the outer framework around inlaid sections.
3. Lengthens the life and preserves the **texture** of the finish by eliminating dust and grime, removal of which is expensive and likely to do damage.
4. Lessens the day-to-day "dusting" required.

etallic Exhibits

1. Reduces maintenance and lengthens life of iron, zinc, copper and brass objects by removing from the air excessive moisture and acid-forming gases that combine chemically with these metals.
2. Minimizes tarnishing of silver by removing sulfur compounds from the air. Tarnishing is undesirable because:
  a. Original beauty is concealed
  b. Cleaning is expensive and may result in damage to engravings.

ina and Porcelain

1. Probably minimizes discoloration of valuable pieces, thought to be caused by absorption of microscopic particles of dirt from the air. Real proof of this is lacking, but it has been stated that some pieces that had retained their color quality for centuries in China have turned grey since importation to the United States.

yptology

Although no published record of research ncerning the preservation of mummies s been found, it certainly could be excted that maintenance of constant temrature and reasonably low relative hudities would be beneficial.

Equipment and Systems

The chief problem of the air condition- application engineer has been to den the system to harmonize with the type architecture. Location of outlets and rern air grilles has been complicated by esence of skylights and wall displays in art museums and compact low-ceiling-height book-stack arrangements in libraries. Many of the libraries and museums that have been air conditioned are large, monumental-type buildings. This has favored the use of **central station equipment** for both air handling and refrigeration. These features influence the design of the system:

1. Reheat or independent dehydration must be used to prevent excessive relative humidities when the sensible heat load is low and the latent heat load high.

2. Zoning requirements (caused by variable sun load and occupancy) should be carefully analyzed.

3. Because of the requirement of eliminating SO_2 from the air, spray type dehumidifiers are recommended. Water treatment is generally essential (pH should be maintained between 8.5 and 9.0). An alternate method is to use activated charcoal or other type of absorber.

4. Automatic control systems should have safety devices to prevent over-humidification under any circumstances.

5. System should be suitable for continuous 24-hr operation without involving excessive maintenance costs.

6. Effective air cleaning devices are required.

7. Air distribution ducts and outlets must harmonize with decorative features.

8. Provision must be made to insure quiet operation. This usually requires sound attenuation in the ducts and vibration elimination treatment at the apparatus.

9. Care should be taken in locating steam and water pipes to avoid damage to valuable collections in event of accidental leaks. It is also necessary to locate steam pipes and radiators far enough away from books, etc. to prevent damage from overheating. Curators should be cautioned about hanging tapestries or paintings directly against exterior walls because of the possibility of very high relative humidity, or even condensation, between the object and the wall.

Existing Installations

The need of providing proper air conditioning for museums and libraries is

stressed in the literature comprising the appended bibliography. Review of some design details of noteworthy existing installations may be helpful to application engineers.

In the **Enoch Pratt Free Library** in Baltimore[9] a silica gel air conditioning system is used to condition a space an acre in area and four levels high—three stack levels each 21 ft high, and the main floor which is 25 ft high—plus an art room and lecture room. Four sets of air-handling apparatus are used; refrigeration effect for the after cooling coils is provided by a CO_2 refrigeration machine and water cooler. Air distribution is accomplished by outlets located about 10 ft above the floor level, and return air grilles are located at the ceiling levels.

The **South Hall** at Columbia University[10] in New York has an air conditioned stack space of 15 floor levels, each approximately 7 ft high, extending from basement to roof in the center of the building. Also conditioned is a 300-seat theatre. Three sets of air handling apparatus are used—one for stack space from basement to 8th floor, one for stack space 9th to 15th floor, and one for the auditorium. Refrigeration is from a central Freon-12 plant. Dehumidifiers are of the spray type. The stack space was designed with a double wall with a clear vertical space of 10 in. between insulated walls. These spaces are used as air plenums. Air outlets are 2-in. slots at ceiling levels.

A 12-tier stack room with a capacity of 10,000,000 volumes is provided with air conditioning at **Annex Building, Library of Congress,**[11] in Washington. Here each deck, 144 ft wide by 322 ft long, has been constructed with a passageway and control room in the center. The outmoded method of providing ventilation by circulating air through deck slits was discarded because: (1) This procedure allowed dust in the lower tiers to be transferred constantly to the upper tiers, (2) heat gathered by the air in circulating made it impossible to maintain an even temperature in both upper and lower tiers, (3) deck slits made it impossible to confine fire to any one deck, and (4) ventilation was uneven since some of the decks contained more books than others. The scheme finally adopted, aft[er] successful tests, introduces the air by je[ts] "strategically" spaced throughout the de[ck] areas. The system thus permits distrib[u]tion throughout each deck independentl[y].

The **James J. Hill Reference Library** [in] St. Paul[14] has been provided with a sy[s]tem which includes two sets of air-han[d]ling apparatus located in the attic spa[ce] directly above the main library room. O[ne] unit is for the main library or auditoriu[m] room. The second unit is for 12 stu[dy] rooms, librarian's office, and 4 catalog a[nd] work rooms. Refrigeration effect is su[p]plied by 300 gal per min. of 52 F w[ell] water. Design of the air-distribution sy[s]tem was a special problem because of t[he] unique building plan. The central readi[ng] room is 150 ft long, 64 ft wide, and 51 [ft] high, with the ceiling a large skylight. Bo[ok] stacks are on the side walls of the ma[in] floor, the second gallery, and the thi[rd] gallery. Air supply to the main room is [by] means of high velocity outlets, with duc[ts] extending longitudinally on each side [of] the room at the third-floor level. Retu[rn] air is taken at the various gallery levels.

In the **Rundel Memorial Building** [in] Rochester, New York,[17] the entire ma[in] floor (reading rooms and various speci[al]ized reference libraries) and public spac[e] on the second floor are air conditioned. Ai[r-] handling apparatus consists of a larg[e] spray-type dehumidifier and three zo[ne] supply fans. All apparatus, including a 16[0-] ton capacity centrifugal refrigeration m[a]chine, is erected in an apparatus room l[o]cated on the fourth-floor level. The att[ic] space above the third floor is utilized f[or] distributing ducts as well as steam and co[n]trol piping. The building is zoned vert[i]cally with separate riser ducts for each co[n]ditioned space. Air outlets on the fir[st] floor are of the high-velocity ceiling typ[e;] side-wall outlets with sectional dampe[rs] are utilized in the second floor rooms.

Careful analysis was made of load dive[r]sity prior to the design of the air conditio[n]ing system for the **Buhl Planetarium** a[nd] Institute of Popular Science, Pittsburgh. As a result use is made of 60 gal per m[in] of 57 F well water, a 3500-gal stora[ge] tank, and two 20-ton refrigeration units.

The system installed in the Harva[rd]

niversity **Rare Book Library**[20] is unusual some respects. Dirt and fumes are re-oved from the incoming air by means of electrostatic air cleaner and an acti-

able 1. Check Figures for Cooling Estimates

Item	Low	Medium	High
oor area per person, sq ft	40	60	80
atts per sq ft floor area	—	1.0	2.0
oom sensible heat, Btu/hr/sq ft	20	35	45
rand total heat, Btu/hr/sq ft	30	51	75
ensible heat factor	.73	.83	.90
oad per person, tons	.12	.23	.40
fm per sq ft floor area	.92	1.6	2.1

ated carbon absorber. Reheat for summer peration is obtained by use of electric ooster heaters. Ducts are lined with sound ttenuation material. Refrigeration is pro-ided by 55 F well water supplemented by) tons of mechanical refrigeration.

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81. HOSPITALS

CONDITIONING of hospital air is mainly confined to operating and recovery rooms, nurseries, delivery and allergy rooms, and to a few other sections where experience has proved its value. Although there are a few hospitals which are completely air conditioned, the general agreement is that the expense of such large-scale projects is not justified except perhaps in the warmer regions of the South. Application requirements in certain wards are outlined below.

Operating and Recovery Rooms

The main purpose in operating-room air conditioning is to reduce possibilities of anesthetic explosions by ventilation and humidification, and to relieve discomfort and nervous strain on the operating staff in warm weather.

Experience has shown that neither a high humidity nor the Horton intercoupler is proof against anesthetic explosions but both help in combatting certain phases of the static spark problem.[1] Conductive pigments are now added to rubber equipment used in operating rooms, including floor covering, footwear of doctors and nurses, sheeting, anesthesia tubing and breathing masks, in an attempt to increase safety.

There is no fixed optimum air condition for operating rooms. The surgical team prefers temperatures between 68 and 75 F, but, for the sake of the patient, the temperature may be increased to as high as 82 F. As a rule, systems are designed to maintain a maximum of 80 F in winter and a minimum of 75 F in summer without recirculation during the period of anesthesia and for sometime after. The recommended relative humidity is 55 to 60 percent.

Ventilation rates of more than 8 to 10 air changes per hour have proved troublesome with most distribution systems, owing to drafts and increased bacterial pollution of air by infected dust deposits being blown off the floor. Such a high air flow is often necessary to remove large amounts of heat from powerful surgical lights, from sterilizing equipment, and from solar radiation on walls and glass.

From the standpoint of patients, cooling of convalescence rooms in warm weather is more important than cooling of operating rooms, because it stimulates recuperation and increases comfort.[2] Hospital authorities recommend that the temperature of the recovery room to which the patient is removed from the operating table be gradually lowered to between 75 and 70 F, according to the condition of the patient, in order to provide the needed stimulation. Humidity is relatively unimportant in recovery rooms, provided it is not too high.

Both central-station plants and individual-room air conditioners have proved satisfactory in operating rooms. The chief disadvantage of self-contained room conditioners is their noise, but the difficulty is gradually being overcome by improvements in design. A separate exhaust fan system is desirable to confine and remove gases and odors. It is preferable to exhaust the used air through an adjoining sterilizing room. Exhaust fan motors, as well as the thermostats and humidistats installed

CONSTANTIN P. YAGLOU, Author Chapter 81. Born 1/26/96 in Constantinople, Turkey. Educated at Robert College, BS, 1919; Cornell University, MME, 1920. Formerly, Research Engineer, ASHVE Laboratories, 1921–25; Instructor to Full Professor, Harvard University, 1926 to date; part-time consultant to various government agencies and commercial concerns since 1930; Lt. Comdr., USN, 1945.

Author of some 100 articles, monographs, etc., on air sanitation, ventilation, air conditioning, and refrigeration in medical and engineering journals; sixteen government reports on clothing, military housing, and aviation medicine.

Member, Amer. Soc. of Heat. and Vent. Engrs., chairman or member various committees; chairman, Mass. Chapter, 1941–42. Fellow, Amer. Public Health Assn., chairman or member of various committees. Member, Amer. Industrial Hygiene Assn.; National Research Council, chairman or member of various committees. Member, Committee on Air Conditioning, Amer. Medical Assn., 1935–48.

At present, Professor of Industrial Hygiene, Harvard School of Public Health, Cambridge, Mass.

inside the operating room, should be sparkproof.

Nurseries and Maternity Wards

In the care of premature infants, the maintenance of a suitable temperature, according to individual requirements, with a relative humidity of about 65 percent, has considerably reduced the incidence of respiratory and gastrointestinal diseases, and improved the infants' chances for life.[3]

The requirements for temperature vary from 75 to 100 F, according to general constitution and body weight. The best air temperature for any infant was found to be the lowest that would stabilize the body temperature with a relative humidity of 65 percent. Significant departures from such optimum air conditions exerted demonstrable harmful effects in these extremely sensitive reactors. When relative humidities between 25 and 50 percent prevailed for two weeks or longer, the body temperature became unstable, irrespective of air temperature, the incidence and severity of digestive syndromes increased, gains in weight diminished, and the mortality rose. On the other hand, air conditions with from 55 to 65 percent relative humidity proved satisfactory over a period of years.

A single nursery conditioned to 77 F temperature and 65 percent relative humidity was found to fulfil the requirements of the majority of premature infants, until they had attained a body weight of 4 to 5 lb. Additional heat for weak infants may be furnished in the cribs, or by means of electric incubators placed inside the conditioned nursery, and the heat adjusted according to individual requirements. In this way the necessity for multiplicity of rooms and of air-conditioning units is obviated; the infants in the heated beds breathe cool, humid air, and the doctors and nurses need not expose themselves to excessive heat and humidity in cold weather.

Most of the older installations are of the central dehumidifier type, providing for humidification and heating in cold weather and for cooling and dehumidification in warm weather. The more recent installations use unit air conditioners installed in an adjoining space or directly inside the nursery. The refrigerating machinery usually installed in the basement. Orig nally, ventilation rates as high as 15 to 2 air changes per hour, without recirculatio seemed to be desirable to remove odors an maintain uniformity of temperature, bu experience has shown that such high rate might do more harm than good by increas ing drafts to which the infants are ex tremely sensitive, and by stirring up dus borne organisms off the floor. With 8 to 1 air changes, and with a space allotment 200 cu ft per infant, fecal odors sometim are perceptible on entering the nurser but they are not particularly objectiona ble.

Individual incubators are now availabl which are completely air conditioned.[4] The added advantage is flexibility of use an better protection of infants from contagio The disadvantages are multiplicity of uni and increased costs in hospitals caring f many infants.

In nurseries for full-term infants, the seems to be little need for year-round a conditioning, although some provisio should be made for ventilation and coo ing excessively warm rooms.

In maternity hospitals which are n completely cooled, there is some fear i lowering the nursery temperature muc below the prevailing ward temperature, ow ing to sudden temperature contrasts i moving infants back and forth to the mothers for nursing. From the standpoin of comfort, excellent results are reported i the cooling of labor and delivery room particularly in the warmer sections of th continent.

Fever Therapy Cabinets

Therapeutic fever has become a valuabl agent in the treatment of many diseases including gonorrhea, neurosyphilis, chorea asthma, peripheral vascular diseases an others. The chief value of air conditionin lies in its ability to preclude burns and t prevent loss of body heat by radiatio convection and evaporation, through th medium of nearly saturated air at a tem perature only a few degrees above that o the body. When heat loss is not prevented an extra amount of heat must be applie to the body to counteract the loss. Thi

imposes an extra strain on the organism and may contribute to dehydration, alcalosis and shock, as indicated by studies of Pijoan and his associates.[5]

In a recent evaluation of relative advantages and disadvantages of various methods for producing systemic fever, Neymann[6] arrived at the conclusion that the method of choice is a combination of electromagnetic induction and air conditioning, the former for raising the body temperature to the desired level, the latter for maintaining the fever for as long as is desired by preventing heat loss. The recent introduction of penicillin in the treatment of gonorrhea and early syphilis, and the use of shortwave and microwave diathermy for selected deep tissue heating have detracted much from the usefulness of the air-conditioned fever cabinet.

Fever therapy cabinets consist of a rectangular or cylindrical insulated box, which is large enough to accommodate a man with his head protruding outside the front end through a rubber collar. The air conditioning apparatus is built in a small rear compartment. The original Kettering "Hypertherm"[7] included electric air and water heaters, a humidifying pan, a fan and a thermostat and humidistat. In a more recent and simplified type, hot tap-water is connected to the sprays, and saturated air at 105 to 115 F is recirculated through the front compartment by means of a fan.

Hay Fever and Pollen Asthma

Hay fever and pollen asthma offer a wide application of air conditioning in the clinic, home or office. Although removal of air-borne pollens is the chief factor in the relief of symptoms, exposure to dust, smoke or gases in the air, or to heat, cold, humidity or drafts is likely to initiate or aggravate the symptoms.[8]

Unlike medical desensitization, treatment by conditioned air is not curative, but gives relief in extrinsic forms of allergy only, as long as patients remain in a pollen-free atmosphere. As a rule, there is a relapse on exposure to pollen-laden air. Allergic conditions due to food, and bacterial asthma are not benefited and may even be aggravated by overcooling and drafts. To a hospital or clinic, a properly conditioned allergy room is valuable in the diagnosis and treatment of complex cases, since failure to obtain relief of symptoms in such a room would indicate that the offending agent is not air-borne. Pollen and dust-free rooms are also useful when desensitization treatment is inadvisable owing to other illness, or when medical methods have proved ineffective.

Cloth or paper filters have proved fairly satisfactory in removing pollens and dusts. Particles less than 10 microns in size are more efficiently removed by electrostatic precipitators. In addition to filtration, a comfortable temperature between 75 and 82 F in warm weather with a relative humidity well below 50 percent appears to be desirable in the experience of Rappaport *et al.*[9]

Cold Therapy and Refrigeration Anesthesia

Cooling of the body to a state of semi-hibernation has been applied to the treatment of hopeless cases of cancer with some success, but the subject is controversial and still in the experimental stage. According to Smith and Fay[10] the lowering of body temperature to 90 F, or less, checks the growth of young cancer cells and relieves pain. Beneficial effects have been observed also in cases of drug addiction,[10] and in dermatologic conditions.[11] The treatment is risky and its therapeutic value remains to be demonstrated.

The use of refrigeration as a shockless anesthetic has been found invaluable in amputations, particularly when cardiac or brain conditions preclude administration of ordinary anesthesia. The underlying principle seems to be that nerves numbed by cold do not transmit impulses, and cold tissues cannot respond with shock.

Chilling of the leg or arm is accomplished in a portable refrigerated unit or by packing the extremity in ice. The limb temperature is gradually reduced to about 10 F above the freezing point. The patient may carry on conversation during amputation, and there are no after-effects; he suffers no hemorrhage, no shock, no nausea, and no change in pulse or blood pressure. The wounds heal better after re-

frigeration than after other means of operation, and the mortality is lower.[12]

Other Hospital Applications

In **inhalation therapy** the use of air conditioning is now almost entirely confined to cooling and dehydration of oxygen tents by means of ice or small condensing units. Excessive carbon dioxide is adsorbed by soda lime. Oxygen chambers of massive metal construction are seldom used now, except for experimental purposes, owing to high initial and operating costs.

Isolation wards are usually not conditioned, and only a few are equipped with mechanical ventilation systems, probably because of fear of spreading infection from one room to another.

X-ray and **physical therapy rooms** are usually well ventilated and sometimes cooled to remove excessive heat and ozone for the comfort of patients and doctors. Storage rooms for X-ray plates and films also require conditioning to prevent deterioration of old and new films.

When funds are available, offices, examination rooms, nurses' rooms and dining rooms are provided with cooling equipment.

Recirculation of Air

Recirculation of hospital air is usually avoided owing to the possibility of transmitting infection from one room to another. Recirculation in operating rooms defeats the main purpose of ventilation by building up bacteria, odors, and gas concentration in the air. The only hospital spaces where recirculation is permissible are offices, patients' rooms or wards, and rooms served by individual units.

Despite this general view, recirculation is sometimes practiced even in operating rooms, perhaps because refrigeration capacity is limited in warm weather. According to a survey of the Committee on Air Conditioning of the American Hospital Association,[2] 11 out of 17 hospitals answering this question reported recirculation rates from 20 to 70 percent with an average of 50 percent.

The practicability of using activated carbon for removing odors, anesthetic gases and bacteria from recirculated hospital air has yet to be established.

Disinfection of Air

Sterilization of air by bactericidal ultraviolet radiation (2537A) appears to have been successfully applied to operating rooms and nurseries, although the evidence is not generally acceptable. According to Hart[13] every surgical wound is heavily contaminated with pathogenic bacteria. In his experience, ultraviolet sterilization of air reduced the number of postoperative wound infections, lessened systemic reaction, shortened convalescence and eliminated occasional death from wound infection.

In nurseries of institutions, Barenberg *et al*,[14] Sauer *et al*,[15] and others, found significant reductions in the incidence and severity of upper respiratory infections by the use of upper air ultraviolet radiation. Wells[16] was able to demonstrate a reduction of measles and mumps by means of germicidal lamps in schoolrooms, but was unable to prove any definite effect on incidence of the common cold.

In theatres, barracks, and other places of assembly where the normal activities of occupants heavily pollute the air with bacteria, upper air irradiation has proved inadequate. Because of poor penetrating power, ultraviolet effectiveness is greatly reduced by moisture, by films of grease, saliva, or mucus surrounding the microorganism, and by dusts and lint to which bacteria are attached and thus protected from radiation.

Treating of floors with spindle oil or with crude liquid paraffin was found effective in reducing air-borne dusts. Experiments by Hollaender and others[17] indicate that upper air irradiation supplemented with floor radiation, is somewhat more effective where danger to the eyes can be precluded.

Various bactericidal mists and vapors have been tried out for disinfecting the air of occupied rooms, with but limited success. Triethylene glycol vapor, which is relatively non toxic, has been studied rather extensively both in the laboratory and in the field. Under favorable laboratory conditions in the absence of dust, one gram of this glycol in about 5000 cf of air produced almost immediate and complete sterilization of air in a small space in which streptococci, pneumococci, and influenza

virus had been sprayed.[18] Results in the field were much less striking, and in some instances they were inconclusive or negative. Triethylene glycol too has proved ineffective against infected dust particles. Of particular interest are studies now in progress at the Metropolitan Life Insurance Company Building where triethylene glycol disinfection of air is being tried out under accurately controlled conditions of humidity and temperature.

Reviews of the present status of ultraviolet and glycol vapor disinfection of air were published by various committees of the American Medical Association,[19] American Public Health Association,[20] and National Research Council.[21]

Ventilation with germ-free air is efficient in diluting air-borne organisms when the pollution is light, but is ineffective against droplets and infected dusts. Too much ventilation may actually increase pollution of air by stirring up organisms and dusts off the floor.[22] Much depends on the design of distribution systems. Under certain conditions, a ventilating system may spread bacteria from a polluted room to other sections of a building.[23] Commercial air washers and filters may remove as much as 80 percent of dust-borne organisms in the air passing through them without much affecting the degree of pollution in the breathing zone of occupied rooms.[22]

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If you searched this chapter for something which was not found in it, please let the editors know.

AUTHOR AND SUBJECT

INDEX

REFRIGERATING DATA BOOK
REFRIGERATION APPLICATIONS VOLUME

INDEX

For properties of various substances such as foods, metals, refrigerants, see quality in question, such as freezing ›ints, specific heat, viscosity, etc.

A

C

D

F

G

H

I

M

P

Q

R

S

T

U

V

Z

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REFRIGERATING DATA BOOK

Refrigeration Applications Volume

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irt & Knox Mfg. Co., 23rd & York Sts., Phila. 32, Pa.
ork Corp., York, Pa. *(p. 119)*

CCESSORIES (See particular kind)

CCUMULATORS

cklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*
ichard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
aker Refrigeration Corp., S. Windham, Me. *(p. 48)*
alifornia Steel Products Co., Barrett & "A" Sts., Richmond, Cal.
oyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
iltrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
ay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
enmore Machine Products, Inc., 15 Depew Ave., Lyons, N.Y.
. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City 7, N.J.
ooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
eco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
emco, Inc., Zelienople, Pa. *(p. 107)*
dw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
emprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*
ilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Wabash Mfg. Co., 2300 S. Western Ave., Chicago 12, Ill.
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
Wildman Boiler & Tank Co., 3026 Carroll Ave., Chicago 12, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

ACCUMULATORS, ICE STORAGE TYPE

Dole Refrigerating Co., 5910 N. Pulaski Rd., Chicago 30, Ill.
King-Zeero Co., 1447 Montrose Ave., Chicago 13, Ill. *(p. 7)*
McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Worthington Pump & Machinery Corp., Harrison), N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

ACTIVATED ALUMINA (See DEHYDRANTS)

ACTIVATED CARBON

Barada & Page, Inc., Guinotte & Michigan Aves., Kansas City 1, Mo.
Carbide & Carbon Chemicals Corp., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.
Darco Corp., Wilmington, Del.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.

ADAPTER FLANGES

Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Mueller Brass Co., Port Huron, Mich.
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.

ADHESIVES (SeealsoCEMENTS; alsoCOMPOUNDS)

Aetna Plywood & Veneer Co., 1731 Elston Ave., Chicago 22, Ill.
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.
Maas & Waldstein Co., 438 Riverside Ave., Newark 4, N.J.
Minnesota Mining & Mfg. Co., 900 Fauquier St., St. Paul 6, Minn.
Plaskon Div., Libbey, Owens, Ford Glass Co., 2112 Sylvan Ave., Toledo 6, O.
Stic-Klip Mfg. Co., 50 Regent St., Cambridge 40, Mass. *(p. 127)*
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

ADSORBENTS (See ACTIVATED CARBON; also DEHYDRANTS)

AERATORS (See WATER COOLERS, BAUDELOT TYPE)

AGITATORS, BRINE, etc.

Arrow Tank Co., Inc., 16 Barnett St., Buffalo 15, N.Y.
Baker Refrigeration Corp., Inc., S. Windham, Me. *(p. 48)*
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 16, Cal.
L. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City 7, N.J.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
Jos. A. Martocello & Co., 229 N. 14th St., Phila. 7, Pa. *(p. 147)*
Nooter Corp., 1426 S. 2nd St., St. Louis 4. Mo.
Piqua Machine & Mfg. Co., Young & College Sts., Piqua, O.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Watson Flagg Machine Co., 845 E. 25th St., Paterson 3, N.J.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

AIR CLEANERS, ELECTRONIC (See also AIR FILTERS)

American Air Filter Co., Inc., 215 Central Ave., Louisville 8, Ky.

(Continued)

AIR CLEANERS (Continued)

Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Raytheon Mfg. Co., Waltham 54, Mass.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., Boston 36, Mass. *(p. 16)*
Trion, Inc., 1000 Island Ave., McKees Rocks, Pa.

AIR CONDITIONERS, PORTABLE, FLOOR & WINDOWSILL TYPE

Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton 1, O.
Allumaloyn Engrg. Co., 220 Seville, Fontana, Cal.
American Coils Co., 25 Lexington St., Newark 5, N.J.
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Fedders-Quigan Corp., 57 Tonawanda St., Buffalo 7, N.Y. *(p. 53)*
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
Hastings Air Conditioning Co., Inc., Hastings, Neb.
Johnson Fan & Blower Corp., 1318 W. Lake St., Chicago 7, Ill.
Kauffman Air Conditioning Corp., 4336 W. Pine Blvd., St. Louis, Mo.
L. & P. Elec. Co., 684 Bedford Ave., Brooklyn, N.Y.
Mitchell Mfg. Co., 2525 Clybourn Ave., Chicago 14, Ill.
Nevinger Mfg. Co., Greenville, Ill.
Pacific Mfg. Corp., 5308 Blanche Ave., Cleveland 4, O.
Philco Corp., Tioga & C Sts., Phila. 34, Pa.
Pleasantaire Corp., 14th & K Sts., N.W., Washington 5, D.C.
Remington Air Cond. Div., 59 E. Court St., Cortland, N.Y.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.

O. A. Sutton Corp., KFH Bldg., Wichita, Kan.
Typhoon Air Conditioning Co., Inc., Div. of Ice Air Conditioning Co., Inc., 794 Union St., Brooklyn 15, N.Y
U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116*
York Corp., York, Pa. *(p. 119*

AIR CONDITIONERS, SELF-CONTAINED

Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 17
Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton 1, O
American Coils Co., 25 Lexington St., Newark 5, N.J.
Baker Refrigeration Corp., S. Windham, Me. *(p. 48*
M. Blazer & Son, 173 Market St., Passaic, N.J.
Bryant Heater Co., 17825 St. Clair Ave., Cleveland 10, O
Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. *(p. 200*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45*
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlen Ave., St. Louis 20, Mo. *(p. 49*
Fedders-Quigan Corp., 57 Tonawanda St., Buffalo 7 N.Y. *(p. 53*
Frick Co., Waynesboro, Pa. *(p. 44*
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6*
General Elec. Co., Air Conditioning Dept., 5 Law rence St., Bloomfield, N.J. *(p. 66*
General Refrigeration Div., Yates-American Ma chine Co., Beloit, Wis. *(p. 55*
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoe nix, Ariz.
Governaire Corp., P. O. Box 1654, Oklahoma City, Okla
Jaden Mfg. Co., Hastings, Neb.
Kauffman Air Conditioning Corp., 4336 W. Pine Blvd St. Louis, Mo.
Mitchell Mfg. Co., 2525 Clybourn Ave., Chicago 14, Ill.
Nevinger Mfg. Co., Greenville, Ill.
Philco Corp., Tioga & C Sts., Phila. 34, Pa.
Remington Air Cond. Div., 59 E. Court St., Cortland N.Y.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinne Heating & Ventilating Co., Inc., 1948 N. 9th St St. Louis 6, Mo.
Servel, Inc., Evansville 20, Ind.
B. F. Sturtevant Div., Westinghouse Elec Corp., 10 Readville St., Boston 36, Mass. *(p. 16*
Supreme Elec. Products Co., 194 Vassar St., Rochester 7 N.Y.
Trane Co., La Crosse, Wis. *(p. 12*
Typhoon Air Conditioning Co., Inc., Div. of Ice Ai Conditioning Co., Inc., 794 Union St., Brooklyn 1 N.Y.
United Air Conditioning Corp., 74 Varick St., N.Y.C. 1
U.S. Air Conditioning Corp., Como Ave., S.E, at 33r St., Minneapolis 14, Minn.
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 11*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Il
York Corp., York, Pa. *(p. 11*

AIR CONDITIONING COILS, CHILLED WATER
(C—also with cleanable tubes)

(C) Aerofin Corp., 410 Geddes St., Syracuse, N.Y. *(p. 1*
American Coils Co., 25 Lexington St.. Newark 5, N.J.
(C) Buffalo Forge Co., 217 Mortimer St., Buffal N.Y. *(p. 9*
(C) Bush Mfg. Co., 179 South St., W. Hartford 10Ct *(p. 20*
(C) Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Conditionaire Unit Co., Div. of Howe Ice Machin Co., 2815 Montrose Ave., Chicago 18, Ill. *(p. 20*
(C) Drayer-Hanson, Inc., 3301 Medford St., Los Angele 33, Cal.
C. A. Dunham Co., 400 W. Madison St., Chicago 6, Ill.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O *(p. 6*
G & O Mfg. Co., 138 Winchester Ave., New Haven 8, C
(C) General Elec. Co., Air Conditioning Dept., Lawrence St., Bloomfield, N.J. *(p. 6*
(C) General Refrigeration Div., Yates-America Machine Co., Beloit, Wis. *(p. 5*
(C) Halstead & Mitchell, Bessemer Bldg., Pittsburg 22, Pa. *(p. 5*

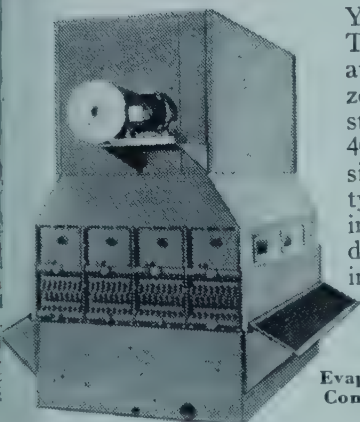
(Continu

YOUNG RADIATOR COMPANY

General Offices: Racine, Wisconsin, U.S.A.
Plants at Racine, Wisconsin and Mattoon, Illinois

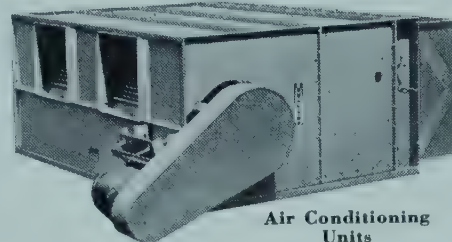
Air Conditioning Equipment, Cooling Coils, Heating Units

)ffices in Principal Cities — Dept. 550



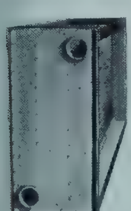
Evaporative Condensers

YOUNG AIR CONDITIONING UNITS are available in eight horizontal and eight vertical styles, in capacities from 400 to 16,625 CFM. Designed to fit every size and type installation for heating, cooling, humidifying, dehumidifying and filtering.

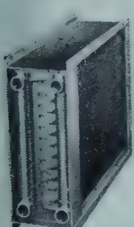


Air Conditioning Units

YOUNG EVAPORATIVE CONDENS-
ERS combine the effect of forced air delivery with that of evaporation. Low water makeup rate is achieved and wind losses are eliminated. Various sizes for any requirement; capable of cooling temperatures within 10° wet bulb.



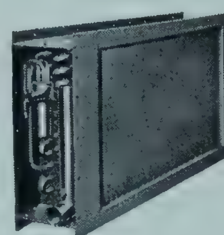
Type "K" Water Coil



Type "W" Water Coil

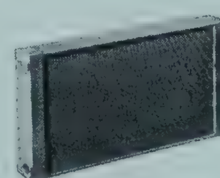
YOUNG WATER COILS are designed for use with cold or hot water. Can be installed for cooling alone or as a part of equipment handling complete or partial air conditioning. Type "K" coils have removable headers to simplify cleaning. Type "W" coils have continuous tubes for multi-pass circulation. Both types are available in a wide choice of sizes and capacities.

YOUNG DIRECT EXPANSION EVAPORATORS are designed for mechanical refrigerating systems that use Freon or methyl chloride as the cooling agent. Available in a variety of sizes, these units incorporate the new Young liquid distributor.



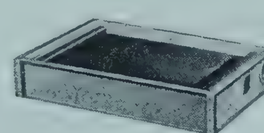
Evaporator Coil

YOUNG COMMERCIAL HEAT TRANSFER UNITS provide the perfect heat transfer surface for application with heating and air conditioning installations where a compact and efficient coil is required.



Commercial Heat Transfer Unit

YOUNG BLAST UNITS and BOOSTER UNITS may be used for various applications in connection with forced air heating and conditioning systems. These units are completely encased heat transfer surfaces and are made in a wide range of sizes and capacities.



Blast Unit

YOUNG HEAT TRANSFER PRODUCTS

Young Quality

T. M. REG. U. S. PAT. OFF.

YOUNG RADIATOR CO.

Dept. 550, Gen. Offices: Racine, Wis., U.S.A.
Plants at Racine, Wis., and Mattoon, Ill.
Sales and Engineering Offices in all Principal Cities

HEATING, COOLING AND AIR CONDITIONING PRODUCTS
Convectors • Unit heaters • Heating coils • Cooling coils • Evaporative condensers • Air conditioning units •

AUTOMOTIVE AND INDUSTRIAL PRODUCTS
Gas, gasoline, Diesel engine cooling radiators • Jacket water coolers • Heat exchangers • Intercoolers • Condensers • Evaporative coolers • Oil coolers • Gas coolers • Atmospheric cooling and condensing units • Supercharger intercoolers • Aircraft heat transfer equipment.

AIR CONDITIONING COILS (Continued)

(C) Industrial Mfg. & Engrg. Co., 3845 N. Ravenswood Ave., Chicago 13, Ill.
Kennard Corp., 1819 S. Hanley Rd., St. Louis 17, Mo. *(p. 8)*
Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. *(p. 202)*
Long Mfg. Div., Borg-Warner Corp., 12501 Dequindre St., Detroit 12, Mich.
(C) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
(C) Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. *(p. 205)*
Modine Mfg. Co., Racine, Wis.
(C) John J. Nesbitt, Inc., Phila. 36, Pa. *(p. 11)*
(C) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
Reese & Long Refrigeration Products, Inc., 408 E. 25th St., N.Y.C. 10
Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
(C) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
Rome-Turney Radiator Co., Rome, N.Y. *(p. 39)*
V. E. Sprouse Co., Inc., Columbus, Ind.
(C) B. F. Sturtevant Div., Westinghouse Elec. Corp. 101 Readville St., Boston 36, Mass. *(p. 16)*
(C) Super Radiator Corp., 6714 Walker St., St. Louis Park, Minneapolis 16, Minn.
Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(C) Trane Co., La Crosse, Wis. *(p. 12)*
Typhoon Air Conditioning Co., Inc., Div. of Ice Air Conditioning Co., Inc., 794 Union St., Brooklyn 15, N.Y.
(C) U.S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(C) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*
(C) Young Radiator Co., Racine, Wis. *(p. 9)*

AIR CONDITIONING COILS, DIRECT EXPANSION

Aerofin Corp., 410 Geddes St., Syracues, N.Y. *(p. 15)*
American Coils Co., 25 Lexington St., Newark 5, N.J.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
Bush Mfg., 179 South St., W. Hartford 10, Ct. *(p. 200)*
Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Conditionaire Unit Co., Div. of Howe Ice Machine Co., 2815 Montrose Ave., Chicago 18, Ill. *(p. 204)*
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
C. A. Dunham Co., 400 W. Madison St., Chicago 6, Ill.
Frick Co., Waynesboro, Pa. *(p. 44)*
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. *(p. 58)*
Hastings Air Conditioning Co., Inc., Hastings, Neb.
Industrial Mfg. & Engrg. Co., 3845 N. Ravenswood Ave., Chicago 13, Ill.
Kennard Corp., 1819 S. Hanley Rd., St. Louis 17, Mo. *(p. 8)*
Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. *(p. 202)*
Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. *(p. 209)*
Long Mfg. Div., Borg-Warner Corp., 12501 Dequindre St., Detroit 12, Mich.
McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. *(p. 205)*
Modine Mfg. Co., Racine, Wis.
Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
Reese & Long Refrigeration Products, Inc., 408 E. 25th St., N.Y.C. 10
Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207*
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211*
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
Rome-Turney Radiator Co., Rome, N.Y. *(p. 39*
Shaw-Kendall Engrg. Co., 120 S. Superior St., Toledo 4 O
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., *(p. 16*
Super Radiator Corp., 6714 Walker St., St. Louis Park Minneapolis 16, Minn.
Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
Trane Co., La Crosse, Wis. *(p. 12*
Typhoon Air Conditioning Co., Inc., Div. of Ice Air Conditioning Co., Inc., 794 Union St., Brooklyn 15, N.Y
U. S. Air Conditioning Corp., Como Ave., S.E., at 33r St., Minneapolis 14, Minn.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis *(p. 4*
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 11*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Il
York Corp., York, Pa. *(p. 11*
Young Radiator Co., Racine, Wis. *(p.*

AIR CONDITIONING COILS, HEATING, HO WATER

Aerofin Corp., 410 Geddes St., Syracuse, N.Y. *p. (1*
American Coils Co., 25 Lexington St., Newark 5, N.Y.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N. *(p. 9*
Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. *(p. 20*
Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Curtis Refrigerating Machine Div., Curtis Mfg. Co 1949 Kienlein Ave., St. Louis 20, Mo. *(p. 4*
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 3 Cal.
G & O Mfg. Co., 138 Winchester Ave., New Haven 8, C
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 6*
Industrial Mfg. & Engrg. Co., 3845 N. Ravenswood Ave Chicago 13, Ill.
Kennard Corp., 1819 S. Hanley Rd., St. Louis 1 Mo. *(p.*
Kramer Trenton Co., Olden & Breuning Aves Trenton 5, N.J. *(p. 20*
Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, G *(p. 20*
McQuay, Inc., 1600 Broadway, N.E., Minneapolis 1 Minn. *(p. 20*
Marlo Coil Co., 6135 Manchester Ave., St. Louis 1 Mo. *(p. 20*
Modine Mfg. Co., Racine, Wis.
C. F. Moores Co., Inc., 1123 Ivy Hill Rd., Wyndmoo Phila. 18, Pa.
John J. Nesbitt, Inc., Phila. 36, Pa. *(p. 11*
Peerless of America, Inc., 2901 Lawrence Ave., Chicag 25, Ill.
Reese & Long Refrigeration Products, Inc., 408 E. 25t St., N.Y.C. 10
Refrigeration Appliances, Inc., 917 W. Lake St., Chicag 7, Ill.
Refrigeration Economics Co., Inc., 1231 E. Tus carawas St., Canton 4, O. *(p. 207*
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., L Angeles, Cal. *(p. 211*
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
Rome-Turney Radiator Co., Rome, N.Y. *(p. 3*
Shaw-Kendall Engrg. Co., 120 S. Superior St., Toledo O.
V. E. Sprouse Co., Inc., Columbus, Ind.
B. F. Sturtevant Div., Westinghouse Elec. Corp 101 Readville St., Boston 36, Mass. *(p. 1*
Super Radiator Corp., 6714 Walker St., St. Louis Par Minneapolis 16, Minn.
Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
Trane Co., La Cross, Wis. *(p. 12*

(Continu

IRBO-VACUUM COMPRESSORS

he Trane Turbo-Vacuum Compressor a centrifugal water chiller for the rger air conditioning jobs. This viation-free water chiller is virtually a mplete air conditioning equipment om placed in an easily installed single iit.

ANE DRY EXPANSION CHILLERS

he Trane Dry Expansion Chiller is esigned to provide chilled water for rious comfort and process cooling bs. In this unit the refrigerant is cirulated in the tubes of a coil contained ithin the outer shell. Water is passed ver the tubes and chilled. Trane Dry xpansion Chillers have over 3,000 ariations in a wide range of capacities.

RANE AIR WASHERS

Trane Air Washers are of strong waterroof construction, designed to give sting trouble-free service. These units ome in 5 foot, 7 foot and 9 foot lengths n one stage units. Two stage units are lso available. Capacities of Trane Air Vashers range from 3,000 to 70,000 fm.

RANE CENTRIFUGAL FANS

Recommended for all types of heating, cooling, ventilating and air handling applications. Available in both forward curved and backwardly inclined blade designs, belt or direct drive, single or double widths. Wheel diameters (forward inclined), 4½" to 108"; (backward inclined): 12" to 108".

TRANE EVAPORATIVE COOLERS

Designed for cooling fluids in a closed system, such as quenching oil, engine jacket water, engine lubricating oil, etc. Using this type of unit eliminates the possibility of contaminating the liquid being cooled and affords cooling without direct contact of fluids with the air.

TRANE COOLING TOWERS

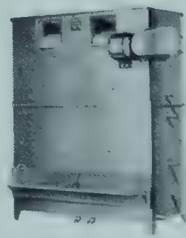
Trane Cooling Towers are available in a variety of sizes from 40 gpm to 360 gpm.

TRANE PRODUCT COOLERS

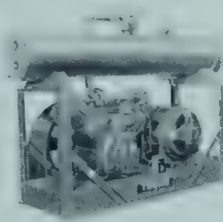
Trane Product Coolers for forced circulation of refrigerated air in walk-in boxes come in 10 sizes with a wide range of capacities.

TRANE CIRCULATING PUMPS

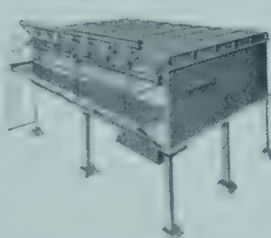
The Trane Type SSU Pump is precision built for mounting directly on the driving motor. Available in five sizes from 1" through 2½" with maximum capacity of 250 gallons per minute against 80 feet, or 125 gallons per minute against a maximum head of 120 feet.



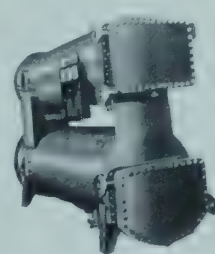
Evaporative Condenser KN Series Model



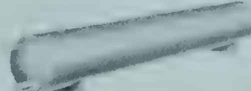
Model 25 CW Condenser



Dry Type Fluid Cooler GC Series



100-ton Turbo-Vacuum Unit



Trane Dry Expansion Chiller

Large FC Centrifugal Fan

UNITRANE

Incorporating modern beauty with the latest in air conditioning developments, the revolutionary new UniTrane represents the finest in multi-room air conditioning. UniTrane is ductless, employing a patented moisture controller that is exclusively Trane to give completely independent moisture and temperature control. This feature makes UniTrane the only system that separately processes ventilation air within the unit, entirely eliminating expensive, space consuming ductwork. Each unit is independent from the other, giving full tenant control and increased flexibility.

TRANE DRY TYPE FLUID COOLER

Condenses refrigerants by air cooling, eliminating water loss and extensive water treatment. Condenses gases in closed system with minimum maintenance. Also suited for cooling engine jacket water and lubricating oil, process cooling and condensing. Available in 22 sizes, with vertical or horizontal air flow.

TRANE AIR CONDITIONING MANUAL

Trane offers the engineering profession an unbiased textbook covering the fundamentals of air conditioning. The Manual not only shows how to design every type of system, but clarifies the underlying principles as well, enabling both student and engineer to reason out their own problems. Price $5.00.

TRANE REFRIGERATION MANUAL

Published primarily as an aid in understanding and correcting installation, maintenance and repair problems. Price $1.50.

OTHER TRANE EQUIPMENT

The complete Trane Line also includes —1. Trane Unit Ventilators for schoolroom air conditioning; 2. Trane Condensation and Centrifugal Pumps for a large variety of uses; 3. Trane Force-Flo Heaters for quiet heat and neat appearance; 4. Trane Railroad and Bus Air Conditioning Equipment of all kinds; 5. Trane Shell and Tube Heat Exchangers for cooling and heating vapors or liquids in a closed system; 6. Transformer Oil Coolers; 7. Convector-radiators; 8. Heating Coils; 9. Unit Heaters—propeller and blower; 10. Roof Ventilators; 11. Steam Heating Specialties; 12. Hot Water Specialties; 13. Wall-Fin Heaters.

AIR CONDITIONING COILS (Continued)

Typhoon Air Conditioning Co., Inc., Div. of Ice Air Conditioning Co., Inc., 794 Union St., Brooklyn 15, N.Y.
U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*
Young Radiator Co., Racine, Wis. *(p. 9)*

AIR CONDITIONING COILS, HEATING, STEAM
(F—Freeze Proof Construction available)

(F) Aerofin Corp., 410 Geddes St., Syracuse, N.Y *(p. 15)*
(F) Airtherm Mfg. Co., 708 S. Spring Ave., St. Louis 10, Mo.
American Coils Co., 25 Lexington St., Newark 5, N.J.
(F) Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
(F) Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. *(p. 200)*
(F) Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlein Ave., St. Louis 20, Mo. *(p. 49)*
(F) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(F) G & O Mfg..Co., 138 Winchester Ave., New Haven 8, Ct.
(F) General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
Hastings Air Conditioning Co., Inc., Hastings, Neb.
(F) Industrial Mfg. & Engrg. Co., 3845 N. Ravenswood Ave., Chicago 13, Ill.
(F) Kennard Corp., 1819 S. Hanley Rd., St. Louis 17, Mo. *(p. 8)*
King Co., 902 N. Cedar St., Owatonna, Minn.
Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. *(p.202)*
Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. *(p. 209)*

(F) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 20*
(F) Marlo Coil Co., 6135 Manchester Ave., St. Loui 10, Mo. *(p. 20*
Modine Mfg. Co., Racine, Wis.
(F) John J. Nesbitt, Inc., Phila. 36, Pa. *(p. 1*
(F) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
Reese & Long Refrigeration Products, Inc., 408 E. 25 St., N.Y.C. 10
Refrigeration Appliances, Inc., 918 W Lake St., Chicag 1, Ill.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 20*
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Lo Angeles, Cal. *(p. 21*
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
(F) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill
Rome-Turney Radiator Co., Rome, N.Y. *(p. 3*
Shaw-Kendall Engrg. Co., 120 S. Superior St., Toledo 4,
V. E. Sprouse Co., Inc., Columbus, Ind.
(F) B. F. Sturtevant Div., Westinghouse Elec. Corp 101 Readville St., Boston 36, Mass. *(p. 1*
Super Radiator Corp., 6714 Walker St., St. Louis Par Minneapolis 16, Minn.
Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(F)Trane Co., La Crosse, Wis. *(p. 1*
(F) Typhoon Air Conditioning Co., Inc., Div. of Ice A Conditioning Co., Inc., 794 Union St., Brooklyn 1 N.Y.
(F) U. S. Air Conditioning Corp., Como Ave., S.E., 33rd St., Minneapolis 14, Minn.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis *(p. 4*
(F) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 11*
York Corp., York, Pa. *(p. 11*
(F) Young Radiator Co., Racine, Wis. *(p.*

AIR CONDITIONING FAN COIL UNITS
(C—Ceiling mounted; F—Floor mounted)

(F) American Coils Co., 25 Lexington, St., Newark 5, N
(C,F) Baker Refrigeration Corp., S. Windham, Me *(p. 4*
(C)Betz Corp., 445 State St., Hammond, Ind.
M. Blazer & Son, 173 Market St., Passaic, N.J.
(C,F) Buffalo Forge Co., 217 Mortimer St., Buffal N.Y. *(p. 9*
(C,F) Bush Mfg. Co., 179 South St., W. Hartford Ct. *(p. 20*
(C,F) Carrier Corp., 302 S. Geddes St., Syracuse N.Y. *(p.*
(C,F) Clarage Fan Co., Porter St., Kalamazoo 16, Mic
(C) Conditionaire Unit Co., Div. of Howe Ice Machine Co., 2815 Montrose Ave., Chicago 18, Il *(p. 20*
Curtis Refrigerating Machine Div., Curtis Mfg. Co 1949 Kienlein Ave., St. Louis 20, Mo. *(p. 4*
(C,F) Drayer-Hanson, Inc., 3301 Medford St., L Angeles 33, Cal.
(F) Frick Co., Waynesboro, Pa. *(p. 4*
(C) Frigidaire Div., Gen'l. Motors Corp., Dayton O. *(p.*
(C,F) General Elec. Co., Air Conditioning Dept. Lawrence St., Bloomfield, N.J. *(p. 6*
(C,F) Governaire Corp., P.O. Box 1654, Oklahoma Ci Okla.
(C,F) Hastings Air Conditioning Co., Inc., Hastin Neb.
(C) Jaden Mfg. Co., Hastings, Neb.
(C,F) Kauffman Air Conditioning Corp., 4336 W. Pi Blvd., St. Louis, Mo.
(C,F) Kennard Corp., 1819 S. Hanley Rd., St. Lou 17, Mo. *(p. 1*
(C) King Co., 902 N. Cedar St., Owatonna, Minn.
(C) Kramer Trenton Co., Olden & Breuning Ave Trenton 5, N.J. *(p. 2*
(C,F) Larkin Coils, 519 Memorial Dr., S.E., Atlan 1, Ga. *(p. 2*
(C,F) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 2*
(C,F) Marlo Coil Co., 6135 Manchester Ave., S Louis 10, Mo. *(p. 2*
(C,F) Merchant & Evans Co., 2035 Washington Av Phila. 46, Pa.
(C,F) Modine Mfg. Co., Racine, Wis.
(C,F) John J. Nesbitt, Inc., Phila. 36, Pa. *(p.*
(C,F) Niagara Blower Co., 405 Lexington Av N.Y.C. 17 *(p.*

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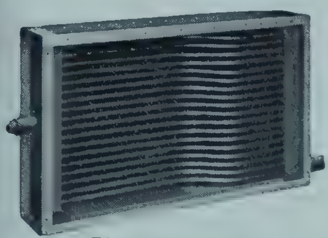
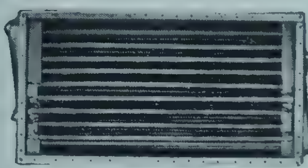
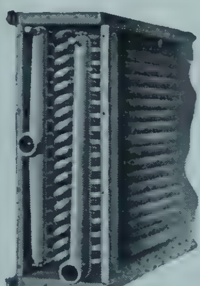

Flexitube Aerofin


Universal Aerofin

AEROFIN
Heat-Exchange Surface


Aerofin Continuous Tube Water Coil

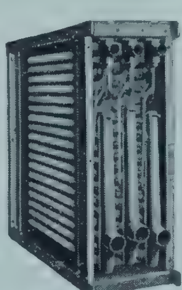

Cleanable Tube Unit with Removable Header

PROVEN PERFORMANCE

• Aerofin fan-system heat-exchange surface is adaptable to meet all practical requirements of refrigeration. The line is complete—for direct-expansion refrigerants and water.

• An unequalled background of development, research and manufacturing is assurance of operating efficiency, long service life and low maintenance costs. Aerofin performance is *proven performance.*


Direct Expansion Unit with Centrifugal Header


Aerofin Direct Expansion Unit

• Send for technical literature or consult your Aerofin district office for the solution of your heat-exchange problem.

AEROFIN CORPORATION
410 South Geddes St., SYRACUSE 1, N. Y.

NEW YORK • CHICAGO • CLEVELAND • DETROIT
PHILADELPHIA • DALLAS • SAN FRANCISCO • TORONTO • MONTREAL

Westinghouse Electric Corporation

Sturtevant Division

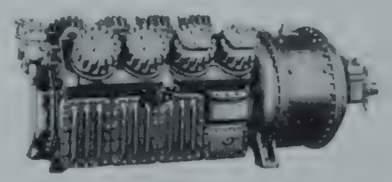
Air Conditioning, Heating, Ventilating, Dust Control and Fume Removal Equipment, Electronic Air Cleaners, Dryers, Compressors, Mechanical Draft Equipment

HYDE PARK BOSTON 36, MASS.

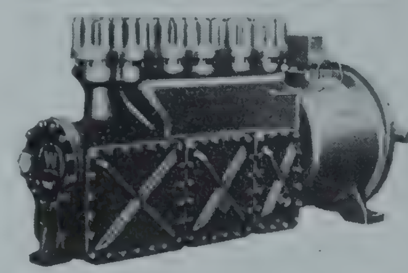
Westinghouse-Sturtevant Division manufactures a complete line of air conditioning equipment for industrial and commercial applications, for both comfort and process air conditioning. Offices and Distributors are located in principal cities. Refer to your local classified telephone directory. Additional product data on all equipment is available on request.

REFRIGERANT COMPRESSORS—Hermetically Sealed, Freon 12, Type CLS refrigerant compressors are designed for air conditioning and industrial refrigeration applications requiring suction evaporating temperatures ranging from 10°F. to 50°F.

The hermetically-sealed compressors are reciprocating multi-cylinder, in-line type in sizes 7½ to and including 60 horsepower; 90 degree V-type on the 2, 3, 5, 75 and 100 horsepower sizes. They are protected by manually reset high and low pressure switch. Driving motors are polyphase, refrigerant-cooled induction type. Motors are protected by thermal overload protection in the De-ion magnetic line-starters.



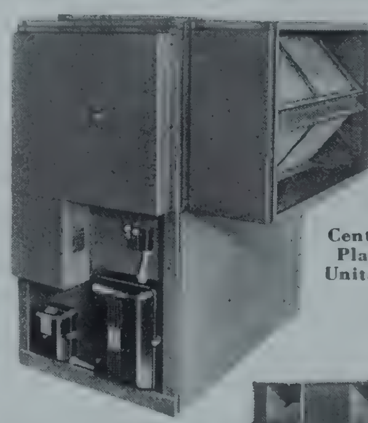
Sixteen-Cylinder V-Type Compressor



Six-Cylinder In-Line Type Compressor

Mounting supports are available to permit mounting the compressor and suitable Westinghouse water-cooled condenser as a unit. Type CLS compressors are made in 12 sizes ranging in nominal capacities of from 2 to 100 tons refrigeration effect.

UNITAIRE* AIR CONDITIONING UNITS—Central-plant Type Unitaires are completely self-contained, with all the component parts on an air conditioning system, designed especially for installation with supply and return air ducts. Unitaires are completely assembled, piped, refrigerant charged, wired and adjusted at the factory. Each is given a complete operating test to assure satisfactory functioning when installed. All that is required is connection of water and electrical service and attachment to the duct system.



Central Plant Unitaire

SELF-CONTAINED TYPE UNITAIRES are widely used in small stores, restaurants, office suites and similar establishments. Usually they are installed in the room to be air conditioned, but in many cases they are remotely located with ducts supplying one or more spaces with conditioned air.

EVAPORATIVE CONDENSERS—Where water is scarce or expensive, or its use or disposal restricted, the "Aquamiser" provides savings in water consumption. Westinghouse Aquamisers are available to give a range of nominal capacities of 5 tons to 100 tons net refrigeration effect.

"Aquamiser" Evaporative Condenser

* Reg. U.S. Patent Office

Westinghouse Electric Corporation

ATER COOLED CONDENSERS—Where suf-ent water is available from city water supply or ling tower, the water-cooled condenser is eco-nical and efficient. To economically match refrig-tion load requirements, Westinghouse water-led condensers are available in 14 sizes, ranging nominal capacities from 2 to 100 tons net refrig-tion effect.

ATER CHILLING UNITS—For the chilling of ter for distribution to a number of cooling coils, r surface dehumidifiers and for use in industrial ocesses, these efficient water-chilling units range size from 5 to 110 tons net refrigeration effect.

EAT TRANSFER SURFACES—Direct expan-on coils with patented refrigerant distributor, illed-water coils, steam and hot water coils are ailable in a great many sizes for all types of sys-ns.

IR CONDITIONING UNITS—Two types are ailable—a horizontal type for ceiling suspension d a vertical type for floor installation. In the hori-ntal and vertical types, year-round air condi-ning is accomplished by the installation of cooling d dehumidifying surfaces for summer, and heat-g surfaces for winter air conditioning.

IR WASHERS—Three types available—Type H, ith one bank of nozzles, used primarily for humidi-ying; Type C, with two banks of nozzles, used for vaporative cooling, humidifying and dehumidify-ig; and Type S with one bank of nozzles, used for umidifying, especially where space is limited.

URFACE DEHUMIDIFIERS—Available for ither chilled water or directly expanded refrigerant, ese wet surface units control accurately wet and ry bulb conditions in industrial and comfort air onditioning systems. Capacities range from 2000 to 0,000 cfm, with cooling capacities of 5 to 250 tons.

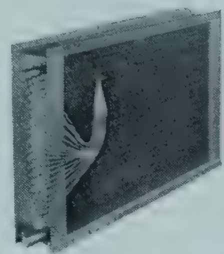
XIFLO PRESSURE FANS are available in either traight through or elbow types, with either three-laded aluminum or 8-bladed steel wheels.

MULTIVANE CENTRIFUGAL FANS are high apacity, low speed fans suitable for use in public uildings because of low tip speed, low outlet ve-ocity, and small size for given duty.

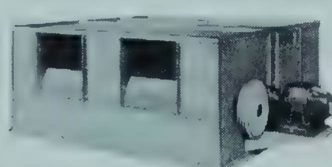
SILENTVANE CENTRIFUGAL FANS are high peed, high efficiency fans engineered for installa-ions where noise cannot be tolerated. These fans ave rising pressure and non-overloading character-stics.

Water-Cooled Condenser

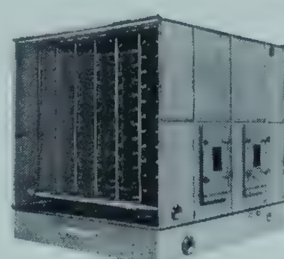
Water Chilling Unit



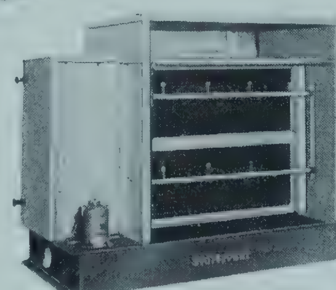
Heat Transfer Surface



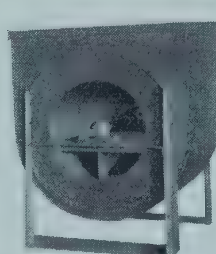
Air Conditioning Unit, Type AH



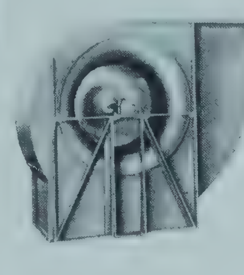
Air Washer



Unit Dehumidifier



Elbow Axiflo Pressure Fan



Silentvane Centrifugal Fan, Design 6

AIR CONDITIONING FAN COIL UNITS (Continued)

(C,F) Peerless of America, Inc., 2901 Lawrence A Chicago 25, Ill.
(C,F) Refrigeration Appliances, Inc., 917 W. Lake Chicago 7, Ill.
(C,F) Refrigeration Economics Co., Inc., 1231 Tuscarawas St., Canton 4, O. *(p. 2*
(C,F) Refrigeration Engrg., Inc., 7250 E. Slaus Ave., Los Angeles, Cal. *(p. 2*
(C) Rempe Co., 340 N. Sacramento Blvd., Chicago 12,
(C,F) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12,
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skin Heating & Ventilating Co., Inc., 1948 N. 9th St., Louis 6, Mo.
(C,F) B. F. Sturtevant Div., Westinghouse El Corp., 101 Readville St., Boston 36, Mass. *(p.*
(C) Tenney Engrg., Inc., 26 Ave B, Newark 5, N.J.
(C,F) Trane Co., La Crosse, Wis. *(p.*
(C,F) Typhoon Air Conditioning Co., Inc., Div. of Air Conditioning Co., Inc., 794 Union St., Brook 15, N.Y.
(C,F) U. S. Air Conditioning Corp., Como Ave., S.E., 33rd St., Minneapolis 14, Minn.
(C,F) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee Wis. *(p.*
Wilson Engrg. Corp., 122 S. Michigan Ave., Chicago 3,
(C,F) Worthington Pump & Machinery Corp., Ha rison, N.J. *(p. 1*
(C,F) XL Refrigerating Co., 1834 W. 59th St., Chic 36, Ill.
(C,F) York Corp., York, Pa. *(p. 1*
(C,F) Young Radiator Co., Racine, Wis. *(p.*

AIR DIFFUSERS (See also GRILLES; also RE- ISTERS)

A-J Mfg. Co., 2119 Washington, Kansas City 8, Mo.
Air Control Products, Inc., Coopersville, Mich.
Air Devices, Inc., 17 E. 42nd St., N.Y.C. 17
Aladdin Heating Corp., 2222 San Pablo Ave., Oakland Cal.
Anemostat Corp. of America, 10 E. 39th St., N.Y 16 *(p.*
Barber-Colman Co., Rockford, Ill.
W. B. Connor Engrg. Corp., 114 E. 32nd St., N.Y.C.
Chas. Demuth & Sons, Inc., 245 Elm Place, Mineola, N
Goettl Bros. Metal Products, Inc., 714 S. Central, Ph nix, Ariz.
Hastings Air Conditioning Co., Inc., Hastings, Neb.
Independent Register Co., 3747 E. 93rd St., Clevelan O.
Minneapolis-Honeywell Regulator Co., 2933-4 Ave., S., Minneapolis 8, Minn. *(p.*
C. F. Moores Co., Inc., 1123 Ivy Hill Rd., Wyndm Phila. 18, Pa.
Pyle-Nat'l. Co., 1371 W. 37th St., Chicago 9, Ill.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skin Heating & Ventilating Co., Inc., 1948 N. 9th St. Louis 6, Mo.
V. E. Sprouse Co., Inc., Columbus, Ind.
Tuttle & Baily, Inc., New Britain, Ct.
U. S. Air Conditioning Corp., Como Ave., S.E., at 3 St., Minneapolis 14, Minn.

AIR DISTRIBUTION PANELS

Cyclone Fence Div., American Steel & Wire Co., U Steel Corp. Subsidiary, P.O. Box 260, Waukega Ill.
Pyle-Nat'l. Co., 1371 W. 37th St., Chicago 9, Ill.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.

AIR FILTERS (See also AIR CLEANERS)

Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 17
Air Devices, Inc., 17 E. 42nd St., N.Y.C. 17
Air Filter Corp., 2514 W. Lisbon Ave., Milwaukee 5, W
Air-Maze Corp., 5200 Harvard Ave., Cleveland 5, O.
Air Stream Filter Corp., 2100 Washington Ave., St. Lo 3, Mo.
American Air Filter Co., Inc., 215 Central Ave., Lou ville 8, Ky.
Blockson & Co., E 5th St., Michigan City, Ind.
A. G. Brauer Supply Co., 2100 Washington Ave., St. L 3, Mo.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Continental Air Filters, Inc., 2520 Helm St., Louisvill Ky.

(Contin

Anemostat Corporation of America

10 East 39th Street, New York 16, N.Y.

No Air Conditioning System Is Better Than Its Air Distribution

ANEMOSTAT DRAFTLESS AIR DIFFUSERS

For refrigeration—Uniform draftless air distribution is essential in food refrigeration and quick freezing plants to eliminate dehydration and to arrest bacterial and enzymatic activities. Proper air diffusion also plays a vital role in increasing the comfort and efficiency of workers. Anemostat Draftless Air Diffusers distribute refrigerated air uniformly and prevent it from stratifying and collecting in stagnant pockets.

For industrial and process air conditioning—In textile mills, dairies, paper mills, bakeries, distilleries, laboratories, printing plants, metal working shops and in many other industrial establishments, scientific climate control and efficient distribution of air are important factors. Various types of Anemostat Air Diffusers are available to meet specific manufacturing and processing problems. Since these patented air diffusers can circulate air of high duct velocities in draftless, low-velocity patterns, they make it possible to install smaller ducts to handle large volumes of air. Anemostats distribute air uniformly to every corner of an enclosure in spite of columns, machinery and other obstacles.

For comfort conditioning—Anemostat Air Diffusers eliminate drafts and stale air pockets . . . equalize temperature and humidity. They are widely used in theatres, stores, office buildings, railroad cars, buses, aircraft and for many other applications where comfort is of prime importance.

ONLY ANEMOSTAT OFFERS THIS EXCLUSIVE ASPIRATION PRINCIPLE

Due to its special design, the Anemostat distributes air of any duct velocity in a multiplicity of planes traveling in all directions. Simultaneously, the unit creates a series of countercurrents traveling toward the device which siphon into the device room air up to 35% of the supply air depending on the type and size of the unit. This room air is mixed with the supply air, within the Anemostat before the air mixture is discharged into the enclosure.

AIR FILTERS (Continued)

Detroit Air Filter Co., P.O. Box 407, Woodstock, Ill.
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Electric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
Farr Co., 2615 Southwest Dr., Los Angeles, Cal.
Filtair Mfg. Co., 487 S. Van Ness Ave., San Francisco 3, Cal.
Glasflos Corp., 155 E. 44th St., N.Y.C. 17
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Hugo Mfg. Co., 49 Ave., W., & Superior St., Duluth 7, Minn.
Logan Engrg. Co., 4801 W. Lawrence, Chicago 30, Ill.
National Air Conditioning, Inc., Johnstown, Pa.
Northern Blower Co., W. 65th St., South of Denison, Cleveland 2, O.
Owens-Corning Fiberglas Corp., 2012 Nicholas Bldg., Toledo 1, O. *(p. 21)*
Research Products Corp., 1015 E. Washington Ave., Madison 3, Wis.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
H. J. Somers, Inc., 6063 Wabash Ave., Detroit 8, Mich.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., Boston 36, Mass. *(p. 16)*
Universal Air Filter Corp., 332 W. Michigan St., Duluth 2, Minn.
Wilson & Co., Inc., 4100 S. Ashland Ave., Chicago 9, Ill.

AIR PURIFICATION EQUIPMENT (See also LAMPS, BACTERICIDAL)

Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 17
Airkem, Inc., 7 E. 47th St., N.Y.C. 17
American Solvent Recovery Corp., 8th Ave. & Cassady Rd., Columbus 3, O.
W. B. Connor Engrg. Corp., 114 E. 32nd St., N.Y.C. 16
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Hanovia Chemical & Mfg. Co., Chestnut St. & N.J.R.R. Ave., Newark 5, N.J.
Johnson Fan & Blower Corp., 1318 W. Lake St., Chicago 7, Ill.
National Air Conditioning, Inc., Johnstown, Pa.
Ohio Carbon Co., 12508 Berea Rd., Cleveland 11, O.
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.

AIR SEPARATORS

Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
W. A. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Strong, Carlisle & Hammond Co., 1932 W. 3rd St., Cleveland 13, O.
Wright-Austin Co., 315 W Woodbridge St., Detroit 26, Mich.

AIR WASHERS & SPRAY TYPE CONDITIONERS

Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 17
Airwasher Corp., Eaton Rapids, Mich.
American Blower Corp., Div. of American Radiator Standard Sanitary Corp., 8111 Tireman Ave., Detroit, 32, Mich.
Bahnson Co., 1001 S. Marshall St., Winston-Salem 7, N.C.
Baker Refrigeration Corp. S. Windham, Me. *(p. 48)*
Bayley Blower Co., 66th & Burnham Sts., Milwaukee 14, Wis.
Bishop & Babcock Mfg. Co., 4901 Hamilton Ave., N.E. Cleveland 14, O.
M. Blazer & Son, 173 Market St., Passaic, N.J.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Comfort Products Corp., 2220 S. La Mesa, Dallas 2, Tex.
Continental Air Filters, Inc., 2520 Helm St., Louisville 1, Ky.
Drying System, Inc., 1810½ Foster Ave., Chicago 40, Ill.
Freshn'd-Aire Co., Div. of Corey Corp., 221 N. La Salle St., Chicago 1, Ill.
Goettl Bros. Metal Products, Inc., 714 S. Central, Pho nix, Ariz.
Kauffman Air Conditioning Corp., 4336 W. Pine Blvd St. Louis, Mo.
D. J. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
National Air Conditioning, Inc., Johnstown, Pa.
National Engrg. & Mfg. Co., 519 Wyandotte, Kansas Cit 6, Mo.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 1 Ill.
Parks-Cramer Co., Box 444, Fitchburg, Mass.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimo 24, Md.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinn Heating & Ventilating Co., Inc., 1948 N. 9th St St. Louis 6, Mo.
Spray Engrg. Co., 114 Central St., Somerville 45, Mas
B. F. Sturtevant Div., Westinghouse Elec. Corp 101 Readville, Boston 36, Mass. *(p. 1*
Trane Co., La Crosse, Wis. *(p. 1*
U. S. Air Conditioning Corp., Como Ave., S.E., at 33 St., Minneapolis 14, Minn.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 4*
Water Cooling Corp., 71 Nassau St., N.Y.C. 7
York Corp., York, Pa. *(p. 11*

ALARM BELLS (See also GAUGES, ALARM)

Automatic Control Co., 1005 University Ave., St. Pa 4, Minn.
Automatic Temperature Control Co., Inc., 5212 Pulas Ave., Phila. 44, Pa.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Pl mouth Rd., Detroit, Mich. *(p. 5*
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, I
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
Signal Engrg. & Mfg. Co., 154 W. 14th St., N.Y.C. 11

ALARMS, LIQUID LEVEL

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Brown Instrument Co., Div. Minneapolis-Honeyw Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10,
Coral Designs, Box 248, Forest Hills, N.Y.
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, I
McDonnell & Miller, Inc., 1316 Wrigley Bldg., Chica 11, Ill.
Standard Thermometer, Inc., 952 Dorchester Ave., B ton 25, Mass.
Wright-Austin Co., 315 W. Woodbridge St., Detroit Ill.
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.

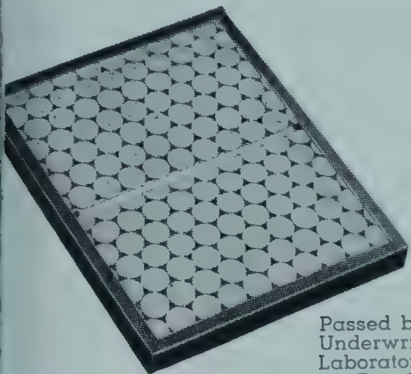
ALCOHOL

Barada & Page, Inc., Guinotte & Michigan Aves., Kan City 1, Mo.
Carbide & Carbon Chemicals Corp., Unit of Union C bide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
E I. du Pont de Nemours & Co., Inc., Wilmington Del.

ALLOYS (See also special type following)

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsbur 22, Pa.
All-State Welding Alloys Co., Inc., 273 Ferris Ave., Wh Plains, N.Y.
American Platinum Wks., 231 New Jersey R.R. Av Newark, N.J.
American Steel & Wire Co., Rockefeller Bldg., Clev land 13, O.
Belmont Smelting & Refining Wks., Inc., 330 Belmo Ave., Brooklyn 7, N.Y.
Bethlehem Steel Co., Bethlehem, Pa.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiar Carnegie Bldg., Pittsburgh 30, Pa.
Carpenter Steel Co., Reading, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago Ill.
W. M. Chace Co., 1601 Beard Ave., Detroit 9, Mich.
Chase Brass & Copper Co., 236 Grand St., Waterbury Ct.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Driver-Harris Co., Harrison, N.J.

(Contin



Passed by The Underwriters' Laboratories, Inc., for Fire Safety.

DUST STOP*

®T. M. REG. U. S. PAT. OFF.

AIR FILTERS

—a OWENS-CORNING FIBERGLAS product

UST-STOP replaceable-type air fil- ›rs effectively and economically ,eanse air of dust, dirt and lint. They re used wherever air is moved me- ıanically, and to protect machinery nd equipment against abrasive dusts.

DUST-STOP Air Filters are made of acks of glass fibers coated with ad- esive, faced with metal grills, framed ı fiberboard. The glass fibers are in- rganic, chemically stable, and resist- :nt to heat, corrosive vapors and most ıcids. The packs are covered with a ıon-odorous, non-evaporating ad- ıesive coating—a coating which is not aken up by the non-absorbent glass ibers. Each impinged dust particle is quickly soaked, acting as a wick to :arry adhesive to other particles.

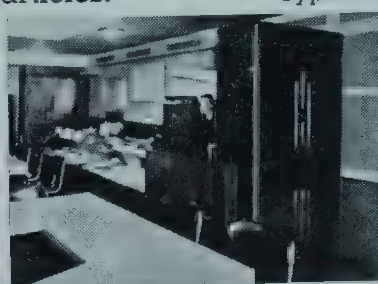
For Large Heating, Ventilating and Air-Conditioning Systems

The efficiency, low cost, ready availability and easy replacement of these standard-sized filters have made them standard equipment on leading makes of air-conditioning and heating equipment.

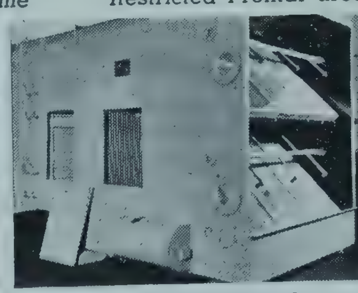
Conventional "L" Type Frame

"V" Type Frame for Restricted Frontal area

In most residential forced-warm-air furnaces and air-conditioners, Dust-Stops are standard equipment.



Dust-Stop Filters are engineered into package air-conditioning units used in commercial establishments.



Fiberglas Aeration Packs are used as contact and eliminator mats in air-washing and humidity control units.

**DUST-STOP is the trade-mark of Owens-Corning Fiberglas Corporation for impingement type air filters made of glass fibers.*

For Complete Information See Sweet's Files or Write:

OWENS-CORNING FIBERGLAS CORPORATION

2012 Nicholas Bldg., Toledo 1, Ohio

Offices: Atlanta, Baltimore, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Columbus, Dallas, Dayton, Denver, Detroit, Grand Rapids, Houston, Kansas City, Louisville, Los Angeles, Milwaukee, Minneapolis, New York, Philadelphia, Pittsburgh, Portland, Richmond, St. Louis, San Francisco, Seattle, Toledo, Tulsa, Washington, D. C.

ALLOYS (Continued)

Duriron Co., Inc., Dayton 1, O.
Eagle Picher Sales Co., American Bldg., Cin'ti. 1, O.
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Handy & Harman, 82 Fulton St., N.Y.C. 7
Arthur Harris & Co., 210 N. Aberdeen St., Chicago 7, Ill.
Haynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
Illinois Zinc Co., 2959 W. 47th St., Chicago 32, Ill.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
National Lead Co., 111 Broadway, N.Y.C. 6
New Jersey Zinc Co., 160 Front St., N.Y.C. 7
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R. I.

ALLOYS, BRAZING

American Platinum Wks., 231 New Jersey R.R. Ave., Newark, N.J.
Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Handy & Harman, 82 Fulton St., N.Y.C. 7
L. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City, 7, N.J.
Charles W. Krieg Co., 48 Dickerson St., Newark 4, N.J. (Preplaced)
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

ALLOYS, DIE CASTING

Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
Bohn Aluminum & Brass Corp., E. Maumee, Adrian, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Federated Metals Div., American Smelting & Refining Co., 120 Broadway, N.Y.C. 5
National Lead Co., 111 Broadway, N.Y.C. 6
New Jersey Zinc Co., 160 Front St., N.Y.C. 7.
Permanente Products Co., 1924 Broadway, Oakland 12, Cal.

ALLOYS, ELECTRICAL

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Carpenter Steel Co., Reading, Pa.
Driver-Harris Co., Harrison, N.J.
Graphite Metallizing Corp., 1013 Nepperhan Ave., Yonkers 3, N.Y.
P. R Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.

ALLOYS, GLASS SEALING

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Carpenter Steel Co., Reading, Pa.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.

ALUMINUM (See **particular mill forms, i.e., BAR, SHEET, etc.**)

AMMETERS (See **METERS, ELECTRIC**)

AMMONIA, ANHYDROUS & AQUA

Armour & Co., 1355 W. 31st St., Chicago 9, Ill.
Barada & Page, Inc., Guinotte & Michigan Aves., Kansa City 1, Mo.
Barrett Div., Allied Chemical & Dye Corp., 40 Recto St., N.Y.C. 6
Henry Bower Chemical Mfg. Co., Gray's Ferry Rd. & 29th St., Phila. 46, Pa.
E. I. du Pont de Nemours & Co., Wilmington 98, Del.
Great Western Div., Dow Chemical Co., 310 Sansome St San Francisco 4, Cal.
Mathieson Chemical Corp., Mathieson Bldg., Baltimor 3, Md.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Phila 7, Pa.

AMMONIA MASKS (See **GAS MASKS**)

AMMONIA SEPARATORS

Baker Refrigeration Corp., S. Windham, Me. *(p. 48*

Cold Control, Inc., 111 Broadway, N.Y.C. 6
Dri-Steam Products, Inc., 29 Broadway, N.Y.C. 6
Reco Products Div., Refrigeration Engrg. Corp., 202 Naudain St., Phila. 46, Pa.
Henry Vogt Machine Co., 10th & Ormsby St., Louisvil 10, Ky.
Wright-Austin Co., 315 W Woodbridge St., Detroit 2 Mich.
XL Refrigerating Co., 1834 W. 59th St., Chicago 6, Ill

ANCHORS, EXPANSION BOLT & SCREW (See als **SHIELDS**)

Chicago Expansion Bolt Co., 1338 W. Concord Place, Chicago 22, Ill.
National Lead Co., 111 Broadway, N.Y.C. 6
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Star Expansion Bolt Co., 147 Cedar St., N.Y.C. 6
Rawlplug Co., Inc., 271 Church St., N.Y.C. 17
U. S. Expansion Bolt Co., York, Pa.

ANGLES (See **SHAPES, STRUCTURAL**)

ANHYDROUS AMMONIA (See **AMMONIA**)

ANODES, PLATING

E. I. du Pont de Nemours & Co., Inc., Wilmington 9 Del.
Hanson-Van Winkle Munning Co., Matawan, N.J.
New Haven Copper Co., Seymour, Ct. (Copper)
New Jersey Zinc Co., 160 Front St., N.Y.C 7
Revere Copper & Brass, Inc., 230 Park Ave., N.Y. 17 *(p. 19*

ASBESTOS (See **INSULATION, ASBESTOS, a mill forms, i.e., SHEET, etc.**)

ASPHALT (See **COMPOUNDS, MASTIC**)

ASSEMBLIES, STAMPED, WELDED, etc.

Acme Equip. Co., 205 E. Broadway, Muskogee, Okla.
Acklin Stamping Co., 1929 Nebraska Ave., Tole 7, O. *(p. 18*
Cuyahoga Stamping Co., 10201 Harvard Ave., Clevela 5, O.
Greene Mfg. Co., Inc., 1028 Douglas Ave., Racine, W
Hunter Pressed Steel Co., 801 Maple St., Lansdale, Pa
Motors Metal Mfg. Co., 5936 Milford Ave., Detroit 1 Mich.
Pent Elec. Co., Inc., 634 Michigan Trust Bldg., Gra Rapids 2, Mich.
V. E. Sprouse Co., Inc., Columbus, Ind.

ATMOSPHERIC COOLERS & ACCESSORIES

Air Equip. Co., 2730 Zuni St., Denver, Col.
Aqua-Mist Co., 426 Jefferson St., Topeka, Kan.
Thomas Beckett & Co., Inc., P.O. Box 7354, Dallas Tex.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N. *(p. 9*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p.*
Central States Mfg. Co., Inc., 1200 S. Summit St., Arkansas City, Kan.
Comfort Products Corp., 2220 S. La Mesa, Dallas 2, T
Farr Co., 2615 Southwest Dr., Los Angeles, Cal.

ttl Bros. Metal Products, Inc., 714 S. Central Ave., Phoenix, Ariz.
nson Fan & Blower Corp., 1318 W. Lake St., Chicago 7, Ill.
kin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. *(p. 209)*
igh Fan & Blower Co., 519 Wyandotte, 128 Linden St., Allentown, Pa.
ional Air Conditioning, Inc., Johnstown, Pa.
ional Engrg. & Mfg. Co.,Kansas City 6, Mo.
gara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
ter Corp. 1426 S. 2nd St., St. Louis 4, Mo.
mer Mfg. Corp., 2200 W. Fillmore, Phoenix, Ariz.
aire Cooler Co., Inc., 141 E. Jackson St., Phoenix, Ariz.
F. Pritchard & Co., 2200 Fidelity Bldg., Kansas City 6, Mo. *(p. 73)*
o Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
frigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
eem Mfg. Co., 570 Lexington Ave., N.Y.C. 22
ode Island Humidifier & Ventilating Co., 99 Chauncey St., Boston 11, Mass.
nplex Mfg. Co., 1135-3rd St., Oakland 20, Cal.
Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St Louis 6, Mo.
A. Sutton Corp., KFH Bldg., Wichita, Kan.
nney Engrg., Inc., 26 Ave. B, Newark 5, N. J.
ermador Elec'l. Mfg. Co., 5119 District Blvd., Los Angeles, Cal.
ane Co., La Crosse, Wis. *(p. 12)*
S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
ility Appliance Corp., 4851 S. Alameda St., Los Angeles 11, Cal.
orthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
rk Corp., York, Pa. *(p. 119)*

TOMIZERS, HUMIDIFYING (See NOZZLES)

UTOMOBILE AIR CONDITIONING SYSTEMS

eco Industries, Inc., Union Trust Bldg., Cincinnati 2, O.

ABBIT METAL (See BEARING MATERIAL)

ACK PRESSURE, etc. (See SUCTION PRESSURE)

ACTERICIDAL LAMPS (See LAMPS, BACTERICIDAL)

AFFLES (See COIL & BAFFLE ASSEMBLIES)

AKERY REFRIGERATORS (See BREAD COOLERS; also DOUGH RETARDERS; also FERMENTATION ROOMS; also PROOF BOXES; etc.)

ALL JOINTS (See SWING JOINTS)

ALLS, FLOAT (See FLOAT BALLS)

ALLS, STEEL BEARING

ew Departure Div., Gen'l. Motors Corp., Bristol, Ct.
ice Ball Bearing Co., 30th & Hunting Park Ave., Phila. 40, Pa.
KF Industries, Inc., Front St. & Erie Ave., Phila. 32, Pa.

AR, ALUMINUM

luminum Co. of America, Pittsburgh 19, Pa.
elmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
ohn Aluminum & Brass Corp., E. Maumee, Adrian, Mich.
entral Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
ermanente Products Co., 1924 Broadway, Oakland 12, Cal.
eynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.
evere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*

BAR, BRASS, BRONZE, COPPER, etc.

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Bristol Brass Corp., Bristol, Ct.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
C. G. Hussey & Co., 2860-2nd Ave., Pittsburgh 19, Pa.
Mueller Brass Co., Port Huron, Mich.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*

BAR, FORGED

Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.

BAR, POWDERED METAL

Amplex Div., Chrysler Corp., 6501 Harper Ave., Detroit 31, Mich.
International Powder Metallurgy Co., 439 W. Main St., Ridgway, Pa.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.

BAR, STEEL

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Bethlehem Steel Co., Bethlehem, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Henry Disston & Sons, Inc., Tacony, Phila. 35, Pa.
Firth-Sterling Steel & Carbide Corp., Demmler Rd., McKeesport, Pa.
Jones & Laughlin Steel Co., Pittsburgh, Pa.
Laclede Steel Co., Arcade Bldg., St. Louis 10, Mo.
McInness Steel Co., Corry, Pa.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Weirton Steel Co., Weirton, W. Va.
Youngstown Sheet & Tube Co., Youngstown, O.

BAR, STEEL, STAINLESS

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Bethlehem Steel Co., Bethlehem, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.

BARE IRON PIPE COILS (See PIPE COILS, BENDS & BENDING)

BARE TUBE COILS

(A—Ammonia B—Other refrigerants)

(A,B) Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
(A,B) Bush Mfg. Co., 179 South St., W. Harftord 10, Ct. *(p. 200)*
(A,B) Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
(A,B) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
(A,B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(A,B) General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. *(p. 58)*
(A,B) Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. *(p. 42)*
(A,B) Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. *(p. 209)*

(Continued)

BARE TUBE COILS (Continued)

(B) McCord Corp., Riopelle & E. Grand Blvd., Detroit 11, Mich. *(p. 37)*
(A,B) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
C. F. Moores Co., Inc., 1123 Ivy Hill Rd., Wyndmoor, Phila. 18, Pa.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
(A,B) National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
(A,B) Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
(A,B) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(A,B) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(B) Reese & Long Refrigeration Products, Inc., 408 E. 25th St., N.Y.C. 10
Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B) Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 267)*
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
(A,B) Reliance Refrigerating Machine Co., 3401 N. Kedzie Ave., Chicago 18, Ill.
(A,B) Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
(A,B) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
(A) Roessing Mfg. Co., Sharpsburg St., Pittsburgh, Pa.
(B) Rome-Turney Radiator Co., Rome, N.Y. *(p. 39)*
(A,B) Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) Vilter Mfg Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(A,B) Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
(A) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
(A,B) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,B) York Corp., York, Pa. *(p. 119)*

BAROMETERS

Bristol Co., Waterbury 91, Ct. (Recording only)
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Fee & Stemwedel, Inc., 2210 Wabansia Ave., Chicago 47, Ill.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Standard Thermometer, Inc., 952 Dorchester Ave., Boston 25, Mass.

BASES CABINET, COMPRESSOR, etc.

Acklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*
Bossert Co., P.O. Drawer 358, Utica 1, N.Y.
Brasco Mfg. Co., Harvey, Ill.
Evans Mfg. Co., 460 S. 10th Ave., Mt. Vernon, N.Y.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago 1, Ind.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee 3, Wis.
Metal Specialty Co., Este Ave. & B&O R.R., Cin'ti., O.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Schnacke, Inc., 1016 E. Columbia St., Evansville 7, Ind.

BASES, INSTRUMENT

Maysteel Products, Inc., 135 W. Wells St., Milwaukee 3, Wis.
Panelyte Div., St. Regis Paper Co., 230 Park Ave., N.Y.C. 17

BASES, MACHINERY

Colonial Iron Wks. Co., 17643 St. Clair Ave., Cleveland 10, O.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago 1, Ind.
L. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City 7, N.J.
Lukenweld, Inc., Coatesville, Pa.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee Wis.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltim 24, Md.

BASES, MOTOR

Ackermann Mfg. Co., Wheeling, W. Va.
Acklin Stamping Co., 1929 Nebraska Ave., Toledo O. *(p. 1*
Electrovent Fan & Mfg. Co., 812 W. Lake St., Chicago Ill.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chica 1, Ind.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee Wis.
Metal Specialty Co., Este Ave. & B&O R.R., Cin'ti., O

BASES, MOTOR, PIVOTED

American Pulley Co., 4200 Wissahickon Ave., Phila. Pa.
H. N. Cook Belting Co., 401 Howard St., San Francisco Cal.
Link-Belt Co., 2045 W. Hunting Park, Phila. 40, Pa.
Rockwood Mfg. Co., 1801 English Ave., Indianap Ind.
Chas. A. Schieren Co., 30 Ferry St., N.Y.C. 7
Southern Belting Co., 236 Forsythe St., S.W., Atlanta Ga.

BASES, VIBRATION ABSORBING (See VIBRATION ABSORBING BASES, etc.)

BASKETS, WIRE (See WIRE FORMING)

BATCH FREEZERS (See FREEZERS)

BAUDELOT COOLERS (See WATER COOLERS BAUDELOT TYPE)

BEARING MATERIAL

Bearium Metals Corp., 268 State St., Rochester, N.Y
Belmont Smelting & Refining Works, Inc., 330 Belm Ave., Brooklyn 7, N.Y.
Bohn Aluminum & Brass Corp., E. Maumee, Adr. Mich.
Bunting Brass & Bronze Co., 715 Spencer St., Toledo 9
Central Steel & Wire Co., 3000 W. 51st St., Chicago Ill.
Eagle Picher Sales Co., American Bldg., Cincinnati 1
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. (Weld Metal)
Federated Metals Div., American Smelting & Refin Co., 120 Broadway, N.Y.C. 5
International Powder Metallurgy Co., 439 W. Main Ridgway, Pa.
Moraine Products Div., Gen'l. Motors Corp., Dayton O.
Mueller Brass Co., Port Huron, Mich.
National Lead Co., 111 Broadway, N.Y.C. 6
Northwest Lead Co., 2700-16th Ave., S.W., Seattle Wash.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.

BEARINGS, BALL

Ahlberg Bearing Co., 3025 W. 47th St., Chicago 32,
Air Controls, Inc., Div. of Cleveland Heater Co., 2310 perior Ave., Cleveland 14, O.
Amplex Div., Chrysler Corp., 6501 Harper Ave., Det 31, Mich.
Bearings Co. of America, 501 Harrisburg Ave., Lancas Pa.
Dodge Mfg. Corp., 505 S. Union St., Mishawaka, In
Equitable Bearing Co., Inc., 1631 Cottage Grove A Chicago, Ill.
Fafnir Bearing Co., 37 Booth St., New Britain, Ct.
Gwilliam Co., 360 Furman St., Brooklyn, N.Y.
Jack & Heintz Precision Industries, Inc., Cleveland 1
Kaydon Engrg. Corp., Muskegon, Mich.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Link-Belt Co., 519 Holmes Ave., Indpls. 6, Ind.
Marlin-Rockwell Corp., 402 Chandler St., Jamesto N.Y.
McGill Mfg. Co., Inc., Valparaiso, Ind.

inger Bearings, Inc., D St., above Erie Ave., Phila. 1, Pa.
ature Precision Bearings, Inc., Carpenter St., Keene, N.H.
Departure Div., Gen'l. Motors Corp., Bristol, Ct.
Ball Bearing Co., 30th & Hunting Park Ave., Phila. 40, Pa.
na-Hoffman Bearings Corp., Hamilton Ave., Stamford, Ct.
ier-Bee Co., 1701 Poland Ave., Detroit 12, Mich.
Industries, Inc., Front St. & Erie Ave., Phila. 32, Pa.
dard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12
hens-Adamson Mfg. Co., Ridgeway Ave., Aurora, Ill.

RINGS, BALL, FOR DRAWERS (See also SLIDES)

Ball Bearing Co., 30th & Hunting Park Ave., Phila. 40, Pa.
Industries, Inc., Front St. & Erie Ave., Phila. 32, Pa.
dard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12
. Wagner Mfg. Co., 4001 N 32nd St., Milwaukee, Wis.

RINGS, GRAPHITE, OILLESS OR SELF-LUBRICATING, etc.

lex Div., Chrysler Corp., 6501 Harper Ave., Detroit 31, Mich.
rium Metals Corp., 268 State St., Rochester, N.Y.
ting Brass & Bronze Co., 715 Spencer St., Toledo 9, O.
eland Graphite Bronze Co., 17000 St. Clair Ave., Cleveland 10, O.
gress Drive Div., Tonn Corp., 3750 E. Outer Drive, Detroit 34, Mich.
. Goodrich Co., 500 S. Main St., Akron, O.
phite Metallizing Corp., 1050 Nepperhan Ave., Yonkers 3, N.Y
rnational Powder Metallurgy Co., 439 W. Main St., Ridgway, Pa.
raine Products Div., Gen'l. Motors Corp., Dayton 1, O.
dall Graphite Products Corp., 609 W. Lake St., Chicago 6, Ill.
eph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
S. Graphite Co., Saginaw, Mich.
l-Met Co., 110 Gougler St., Kent, O.

ARINGS, NEEDLE

nir Bearing Co., 37 Booth St., New Britain, Ct.
ynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
ydon Engrg. Corp., Muskegon, Mich.
ller Bearing Co. of America, Trenton, N.J.

ARINGS, ROLLER

tna Ball & Roller Bearing Co., 4600 Schubert Ave., Chicago 39, Ill.
arles Bond Co., 617 Arch St., Phila., Pa.
dge Mfg. Corp., 505 S. Union St., Mishawaka, Ind.
fnir Bearing Co., 37 Booth St., New Britain, Ct.
villiam Co., 360 Furman St., Brooklyn, N.Y.
ynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
att Bearings Div., Gen'l. Motors Corp., Harrison, N.J.
ydon Engrg. Corp., Muskegon, Mich.
nk-Belt Co., 519 Holmes Ave., Indpls. 6, Ind.
essinger Bearings, Inc., D St., above Erie Ave., Phila 1, Pa.
rma-Hoffman Bearings Corp., Hamilton Ave., Stamford, Ct.
oller Bearing Co. of America, Trenton, N.J.
KF Industries, Inc., Front St. & Erie Ave., Phila. 32, Pa

EARINGS, SLEEVE

etna Ball & Roller Bearing Co., 4600 Schubert Ave., Chicago 39, Ill.
mpco Metal, Inc., 1745 S. 38th St., Milwaukee 4, Wis.
mplex Div., Chrysler Corp., 6501 Harper Ave., Detroit 31, Mich.
earium Metals Corp., 268 State St., Rochester, N.Y.
has. Bond Co., 617 Arch St., Phila., Pa.
unting Brass & Bronze Co., 715 Spencer St., Toledo 9, O.
entral Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago Die Casting Mfg. Co., 2500 W. Monroe St., Chicago 12, Ill.
Cleveland Graphite Bronze Co., 17000 St. Clair Ave., Cleveland 10, O.
R. & J. Dick Co., Inc., 24 Sade St., Passaic, N.J.
Dodge Mfg. Corp., 505 S. Union St., Mishawaka, Ind.
Federal-Mogul Corp., Shoemaker & Lillibridge Sts., Detroit 13, Mich.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Graphite Metallizing Corp., 1050 Nepperhan Ave., Yonkers 3, N.Y.
Haynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
International Powder Metallurgy Co., 439 W. Main St., Ridgway, Pa.
Kaydon Engrg. Corp., Muskegon, Mich.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
McQuay-Norris Mfg. Co., 2320 Marconi Ave., St. Louis 10, Mo.
Moraine Products Div., Gen'l. Motors Corp., Dayton 1, O.
National Lead Co., 111 Broadway, N.Y.C. 6
Randall Graphite Products Corp., 609 W. Lake St., Chicago 6, Ill.
Roller Bearing Co. of America, Trenton, N.J.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Saginaw Bearing Co., 820 S. Water St., Saginaw, Mich.
Shenango-Penn Mold Co., Dover, O.

BEER COOLERS, BOTTLES (See BOTTLED BEVERAGE COOLERS)

BEER COOLERS, DRAFT
(A—Self-contained; B—With coils but without condensing unit; C—No coils or condensing unit)

Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
(A,B) Bemco Mfg. Corp., 1504 Minor at Pike, Seattle 1, Wash.
Horace A. Carter, Inc., 16 E. Marshall St., Richmond 19, Va.
Corbin Cabinet Lock Co., Div. of American Hardware Corp., New Britain, Ct.
Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, Pa.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Fleetwood Airflow, Inc., 421 N. Penna. Ave., Wilkes-Barre, Pa.
(A,B,C) Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.
(A,B) Ed Friedrich Sales Corp., 1117 E. Commerce St., San Antonio 6, Tex.
(A,B,C) Gem Refrigerator Co., 165 W. Wyoming Ave., Phila. 40, Pa.
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 *(p. 122)*
John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
(A,B) Ideal Cooler Corp., 2953 Easton Ave., St. Louis 6, Mo.
(A) Kooler Keg Systems, 11 Mill St., Belleville 9, N.J.
(A,B,C) La Crosse Cooler Co., 2809 Losey Blvd., S., La Crosse, Wis.
Lingle Refrigerator Co., Inc., 1116 E. 15th St., Kansas City 6, Mo.
(A,B) Master-Bilt Refrigeration Mfg. Co., 920 Palm St., St. Louis 7, Mo.
(A,B,C) National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
Nor-Lake, Inc., 2nd & Elm Sts., Hudson, Wis.
(A,B) R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
(A,B) C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
Star Metal Mfg. Co., Inc., Trenton Ave., & Ann St., Phila. 34, Pa.
(B) Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*
(B) Tyler Fixture Corp., 1401 Lake St., Niles, Mich. *(p. 80)*
Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
(A,B) Uniflow Mfg. Co., Erie, Pa.
(C) United Refrigerator Mfg. Co., Inc., 350 Robert St., St. Paul 1, Minn.

BEER LINE INSULATION (See INSULATION)

BELLOWS, METALLIC

Bridgeport Thermostat Co., Inc., 1225 Connecticut Ave., Bridgeport 1, Ct.
Chicago Metal Hose Corp., Maywood, Ill.
Clifford Mfg. Co., 110 Grove St., Waltham 54, Mass. *(p. 27)*
Cook Elec. Co., 2700 Southport Ave., Chicago 14, Ill
Fulton Sylphon Co., Knoxville, Tenn.

BELLS (See ALARMS)

BELTS & BELTING, FLAT

American Pulley Co., 4200 Wissahickon Ave., Phila. 29, Pa.
Baltimore Belting Co., 23 S. Gay St., Baltimore 2, Md.
Chas. Bond Co., 617 Arch St., Phila., Pa.
Boston Woven Hose & Rubber Co., P.O. Box 1071, Boston 3, Mass.
Chicago Belting Co., 113 N. Green St., Chicago 7, Ill.
Chicago Rawhide Mfg. Co., 1306 Elston Ave., Chicago 22, Ill.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
R. & J. Dick Co., Inc., 24 Sade St., Passaic, N.J
Eagle Belting & Leather Co., 1401 Central Pkwy., Cin'ti. 4, O.
Fisher Leather Belting Co., Inc., 325 N. 3rd St., Phila. 6, Pa.
Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.
L. H. Gilmer Co., 7230 Keystone St., Tacony, Phila. 35, Pa.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Groton & Knight Co., 356 Franklin St., Worcester 4, Mass.
E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
Hudson Belting Co., 84 E. Worcester St., Worcester 4, Mass.
Manheim Mfg. & Belting Co., Manheim, Pa.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
J. E. Rhoads & Sons, 35 N. 6th St., Phila. 6, Pa.
Russell Mfg. Co., 400 E. Main St., Middletown, Ct.
Chas. A. Schieren Co., 30 Ferry St., N.Y.C. 7
Southern Belting Co., 236 Forsyth St., S.W., Atlanta 2, Ga.
Thermoid Co., Trenton, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

BELTS & BELTING, VEE

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Pulley Co., 4200 Wissahickon Ave., Phila. 29, Pa.
Baltimore Belting Co., 23 S. Gay St., Baltimore 2, Md.
Boston Woven Hose & Rubber Co., P.O. Box 1071, Boston 3, Mass.
Browning Mfg. Co., Inc., Maysville, Ky.
Congress Drive Div., Tann Corp., 3750 E. Outer Drive Detroit 34, Mich.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
Dayton Rubber Mfg. Co., 2342 W. Riverview Ave., Dayton 1, O.
R. & J. Dick Co., Inc., 24 Sade St. Passaic, N.J.
Eagle Belting & Leather Co., 1401 Central Pkwy., Cin'ti. 4, O.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
L. H. Gilmer Co., 7230 Keystone St., Tacony, Phila. 35, Pa.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Hudson Belting Co., 85 E. Worcester St., Worcester 4, Mass.
Manheim Mfg. & Belting Co., Manheim, Pa.
Maurey Mfg. Corp., 2907 S. Wabash Ave., Chicago Ill.
New York Belting & Packing Co., 1 Market St., Passa N.J.
Pyott Foundry & Machine Co., 328 N. Sangammon S Chicago 7, Ill.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 2 Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.
J. E. Rhoads & Sons, 35 N. 6th St., Phila. 6, Pa.
Chas. A. Schieren Co., 30 Ferry St., N.Y.C. 7
Simonds Gear & Mfg. Co., 2501 Liberty Ave., Pittsbur 22, Pa.
Southern Belting Co., 236 Forsythe St., S.W., Atlanta Ga.
Thermoid Co., Trenton, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C.
V-Belt Clutch Co., 418 N. Western Ave., Los Angeles Cal.
Worthington Pump & Machinery Corp., Harriso N.J. *(p. 11*

BENDING (See PIPE COILS, BENDS & BENDIN

BENDING, SMALL PARTS

American Brass Co., Waterbury 88, Ct. *(p. 1*
Behringer Metal Wks., Inc., 108 Jabez St., Newark N.J.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn N.Y. *(p.*
L. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City N.J.
C. F. Moores Co., Inc., 1123 Ivy Hill Rd., Wyndmo Phila. 18, Pa.
Edw Renneburg & Sons Co., 2639 Boston St., Baltim 24, Md.
V. E. Sprouse Co., Inc., Columbus, Ind.

BENDS (See RETURN BENDS)

BERYLLIUM COPPER

Beryllium Corp., P.O. Box 1462, Reading, Pa.
P. R. Mallory & Co., Inc., 3029 E. Washington S Indpls., Ind.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O

BEVERAGE COOLERS (See BOTTLED BEVERA COOLERS)

BEZELS

L. F. Grammes & Sons, Inc., 365 Union St., Allento Pa.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.

BIMETALS (See THERMOSTATIC BIMETALS)

BLADES, FAN (See FAN BLADES)

BLAST COILS (See AIR CONDITIONING COIL

BLAST FREEZERS (See FREEZERS)

BLENDERS, STEAM-WATER, etc.

Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 1*

BLOCK TIN (See TIN)

BLOOD PLASMA REFRIGERATORS (See R FRIGERATORS, SPECIAL)

BLOWERS, BLOWER WHEELS, HOUSINGS SCROLLS (See also FANS)

Advance Fan & Blower Co., 3428 Bagley, Detroit, Mi
Air Controls, Inc., Div. of Cleveland Heater Co., 2 Superior Ave., Cleveland 14, O.
Aladdin Heating Corp., 2222 San Pablo Ave., Oakland Cal.

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BLOWERS (Continued)

Allington & Curtis Mfg. Co., 1810 Holland Ave., Saginaw, Mich.
American Machine Products Co., Marshalltown, Iowa
American Blower Corp., Div. of American Radiator & Standard Sanitary Corp., 8111 Tireman Ave., Detroit 32, Mich.
Bayley Blower Co., 66th & Burnham Sts., Milwaukee 14, Wis.
Bishop & Babcock Mfg. Co., 4901 Hamilton Ave., N.E., Cleveland 14, O.
M. Blazer & Son, 173 Market St., Passaic, N.J.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
E. K. Campbell Heating Co., 1809 Manchester St., Kansas City 3, Mo.
Campbell Heating Co., 3121 Dean St., Des Moines 4, Ia.
Carling Turbine Blower Co., 25 St. John's Rd., Worcester, Mass.
Century Fan Ventilator Co., 47 Cedar St., Stamford, Ct.
Champion Blower & Forge Co., Harrisburg & Charlotte Sts., Lancaster, Pa.
Chicago Blower Corp., 4588 W. Congress St., Chicago 24, Ill.
Chicago Fan & Fin Coil Co., 1937 Walnut St., Chicago 12, Ill.
Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Colonial Iron Wks. Co., 17643 St. Clair Ave., Cleveland 10, O.
Commercial Shearing & Stamping Co., 1775 Logan St., Youngstown, O.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
Electrovent Fan & Mfg. Co., 812 W. Lake St., Chicago 7, Ill.
Elliott Co., Jeanette, Pa.
Erie Art Metal Co., 1602 E. 18th St., Erie, Pa.
Fasco Industries, Inc., Union & Augusta Sts., Rochester 2, N.Y.
Garden City Fan Co., 332 S. Michigan Ave., Chicago 4, Ill.
General Blower Co., Ferris Ave., Morton Grove, Ill.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Hastings Air Conditioning Co., Inc., Hastings, Neb.
Ilg Elec. & Ventilating Co., 2850 N. Crawford Ave., Chicago 41, Ill.
Jaden Mfg. Co., Hastings, Neb.
Johnson Fan & Blower Corp., 1318 W. Lake St., Chicago 7, Ill.
King Co., 902 N. Cedar St., Owatonna, Minn.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Lehigh Fan & Blower Co., Div. of Heilman Boiler Wks., Inc., 128 Linden St., Allentown, Pa.
Leiman Bros., Inc., 100 Christie St., Newark 5, N.J.
Martin Fan & Blower Co., 4634 W. 21st Place, Chicago 50, Ill.
Jos. A Martocello & Co., 229 N. 14th St., Phila. 7, Pa. *(p. 147)*
Moore Co., 544 Westport Rd., Kansas City 2, Mo.
Morrison Products, Inc., 16816 Waterloo Rd., Cleveland 10, O.
National Engrg. & Mfg. Co., 519 Wyandotte, Kansas City 6, Mo.
Herman Nelson Corp., 1824-3rd Ave., Moline, Ill.
New York Blower Co., 3155 Shields Ave., Chicago 16, Ill.
Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
Peerless Elec. Co., 2000 W. Market St., Warren, O.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Redmond Co., Inc., Owosso, Mich.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Robinson Ventilating Co., Zelienople, Pa.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Schwitzer-Cummins Co., Indpls. 7, Ind.
V. E. Sprouse Co., Inc., Columbus, Ind.
Standard Elec. Mfg. Co., W. Berlin, N.J.
Sterling Blower Co., 791 Windsor St., Hartford 1, Ct.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville, St., Boston 36, Mass. *(p. 16)*
O. A. Sutton Corp., KFH Bldg., Wichita, Kan.
Torrington Mfg. Co., 70 Franklin St., Torrington Ct. *(p. 9*
Trane Co., La Crosse, Wis. *(p. 12*
U. S. Air Conditioning Corp., Como Ave., S.E., at 33r St., Minneapolis 14, Minn.
Utility Appliance Corp., 4851 S. Alameda St., Los Angel 11, Cal.
Viking Air Conditioning Corp., 5600 Walworth Ave Cleveland 2, O.
L. J. Wing Mfg. Co., 154 W. 14th St., N.Y.C. 11

BLOWER FILTER UNITS

Air Controls, Inc., Div. of Cleveland Heater Co., 231 Superior Ave., Cleveland 14, O.
Aladdin Heating Corp., 2222 San Pablo Ave., Oakland 1 Cal.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 9*
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Goettl Bros. Metal Poducts, Inc., 714 S. Central, Phoenix, Ariz.
Johnson Fan & Blower Corp., 1318 W. Lake St., Chicag 7, Ill.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
P. H. MaGirl Foundry & Furnace Wks., 413 E. Oaklar Ave., Bloomington, Ill.
Martin Fan & Blower Co., 4634 W. 21st Place, Chica 50, Ill.
National Air Conditioning, Inc., Johnstown, Pa.
National Engrg. & Mfg. Co., 519 Wyandotte St., Kans City 6, Mo.
Peerless Elec. Co., 2000 W. Market St., Warren, O.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinn Heating & Ventilating Co., Inc., 1948 N. 9th St., S Louis 6, Mo.
U. S. Air Conditioning Corp., Como Ave., S.E., at 33 St., Minneapolis 14, Minn.
Viking Air Conditioning Corp,. 5600 Walworth Av Cleveland 2, O.

BODIES, TRUCK (See TRUCK BODIES, REFRIGER ATED)

BOLTS, CARRIAGE, STOVE, etc.

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y. 13
American Screw Co., 21 Stevens, Providence 1, R.I.
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 1 O.
Bethlehem Steel Co., Bethlehem, Pa.
Boss Nut & Bolt Co., 3403 W. 47th St., Chicago, Ill.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury Ct.
Clark Bros. Bolt Co., Milldale, Ct.
Columbus Bolt Wks. Co., 291 Marconi Blvd., Columb 16, O.
Continental Screw Co., 459 Mt. Pleasant St., New Be ford, Mass.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, I
Lamson & Sessions Co., 1971 W. 85th St., Cleveland O.
National Lock Co., 7th St. & 18th Ave., Rockfor Ill. *(p. 12*
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pitt burgh 3, Pa.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Rockford Screw Products Co., 2501-9th St., Rockford, I
Russell, Burdsall & Ward Bolt & Nut Co., Port Chest N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Lou 15, Mo.
Stronghold Screw Products, Inc., 216 W. Hubbard S Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

BOLTS, EYE (See EYEBOLTS)

BOLTS, EXPANSION

Chase Brass & Copper Co., 236 Grand St., Waterbury Ct.

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BOLTS (Continued)

Chicago Expansion Bolt Co., 1338 W. Concord Place, Chicago 22, Ill.
National Lead Co., 111 Broadway, N.Y.C. 6
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Rawlplug Co., Inc., 271 Church St., N.Y.C. 13
Star Expansion Bolt Co., 147 Cedar St., N.Y.C. 6

BOLTS, LAG

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Bethlehem Steel Co., Bethlehem, Pa.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Clark Bros. Bolt Co., Milldale, Ct.
Columbus Bolt Wks. Co., 291 Marconi Blvd., Columbus 16, O.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Wm. H. Haskell Mfg. Co., 24 Commerce St., Pawtucket, R.I.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. (p. 121)
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

BOLTS, MACHINE, STUD, etc.

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Bethlehem Steel Co., Bethlehem, Pa.
Boss Nut & Bolt Co., 3403 W. 47th St., Chicago 1, Ill.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Clark Bros. Bolt Co., Milldale, Ct.
Cleveland Cap Screw Co., 2917 E. 79th St., Cleveland 4, O.
Columbus Bolt Wks. Co., 291 Marconi Blvd., Columbus 16, O.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. (p. 121)
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago , Il50l.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Star Expansion Bolt Co., 147 Cedar St., N.Y.C. 6
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

BOLTS, PHILLIPS HEAD

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
American Screw Co., 21 Stevens, Providence 1, R.I.
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Lamson & Sessions Co. 1971 W. 85th St., Cleveland 2, O
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. (p. 121)
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

BOLTS, THROUGH

Bethlehem Steel Co., Bethlehem, Pa.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, (
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Lou 15, Mo.
Stronghold Screw Products, Inc., 216 W. Hubbard S Chicago 10, Ill.

BOLTS, TOGGLE

Chicago Expansion Bolt Co., 1338 W. Concord Place, Chi cago 22, Ill.
Goodloe E. Moore Co., 2811 N. Vermilion, Danville, I
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Star Expansion Bolt Co., 147 Cedar St., N.Y.C. 6
U. S. Expansion Bolt Co., York, Pa.

BOLTS, WELD

Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 1 O.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Columbus Bolt Wks. Co., 291 Marconi Blvd., Columb 16, O.
Ohio Nut & Bolt Co., 600 Front St., Berea, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chest N.Y.
Stronghold Screw Products, Inc., 216 W. Hubbard S Chicago 10, Ill.

BOTTLED BEVERAGE COOLERS
(A—Self-contained; B—With coils but without co densing unit; C—No coils or condensing uni

(A,B) American Refrigeration Corp., 2836 Colfax Av S., Minneapolis 8, Minn.
(C) **Annapolis Yacht Yard, Box 791, Annapolis, M** (p. 21
(A) Artkraft Mfg. Corp., Kibby St. & D.T.&I. R. Lima. O.
Bally Case & Cooler Co., Bally, Pa.
(A,B) Carrier Corp., 302 S. Geddes St., Syracuse N.Y. (p.
(A,B) Crandal-Stone Div., Brewer-Titchener Corp., Court St., Binghamton, N.Y.
(A) Crosley Div., Avco Corp., Cin'ti. 25, O.
(A,B) Cruse Refrigerator Co., Inc., 504 W. Main St., Lo isville 2, Ky.
Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, I
Esco Cabinet Co., West Chester, Pa.
(A,B) Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vern N.Y.
(B) Fleetwood-Airflow, Inc., 421 N. Penna Ave., Wilk Barre, Pa.
(A,B,C) Fogel Refrigerator Co., 5400 Eadom St., Phi 37, Pa.
(A,B) Ed Friedrich Sales Corp., 1117 E. Commerce S San Antonio 6, Tex.
(A) **Frigidaire Div., Gen'l. Motors Corp., Dayton O.** (p.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Gem Refrigerator Co., 165 W. Wyoming Ave., Phila. Pa.
(A) **General Elec. Co., Air Conditioning Dept., Lawrence St., Bloomfield, N.J.** (p.
John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
(B) C. V. Hill & Co., Inc., 360 Pennington Ave., Trent 1, N.J.
(A,B) Ideal Cooler Corp., 2953 Easton Ave., St. Louis Mo.
(A) Jewett Refrigerator Co., Inc., 2 Letchworth St., B falo 13, N.Y.
Kelvinator Div., Nash-Kelvinator Corp., 142 Plymouth Rd., Detroit, Mich. (p.
(A,B) Koch Butchers' Supply Co., 600 E. 14th Ave., Kansas City 16, Mo.
(A,B,C) La Crosse Cooler Co., 2809 Losey Blvd., S., Crosse, Wis.
(A,B,C) Jack Langston Co., 3700 Elm St., Dallas 1, T
(A,B) Lingle Refrigerator Co., Inc., 1116 E. 15th St., K sas City 6, Mo.
(A,B) Master-Bilt Refrigeration Mfg. Co., 920 Palm St. Louis 7, Mo.
(B) Morton Show Cases, Inc., Washington Courthou O.

Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
iplex Faucet Co., 4325 Duncan Ave., St. Louis 10, Mo.
,C) National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
,C) Nolin Mfg. Co., Inc., 1100 Madison Ave., Montgomery 2, Ala.
Lake, Inc., 2nd & Elm Sts., Hudson, Wis.
) Perfecold, Inc., 1940 S. Main St., Los Angeles 7, Cal.
) R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
able Elevator Mfg. Co., 920 E. Grove St., Bloomington, Ill.
) Puffer-Hubbard Mfg. Co., Grand Haven, Mich.
W. Allen Rogers Industries, Inc., P.O. Box 272, Demopolis, Ala.
S & S Products, Inc., Lima, O.
) C. Schmidt Co., John & Livingston Sts., Cin'ti. 14,
) Seeger Refrigerator Co., 850 Arcade St., St. Paul 6, Minn.
) Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
Star Metal Mfg. Co., Trenton Ave. & Ann St., Phila. 34, Pa.
dard Mfg. Co., 617-4th St., S.W., Mason City, Ia.
r-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
Tyler Fixture Corp., 1401 Lake St., Niles, Mich. *(p. 80)*
on Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
3) Uniflow Mfg. Co., Erie, Pa.
3,C) United Refrigerator Mfg. Co., Inc., 350 Robert St., St. Paul 1, Minn.
or Products Corp., 901 Pope Ave., Hagerstown, Md.
3) Viking Refrigerators, Inc., 7500 Wilson Ave., Kansas City 3, Mo.
d Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.
3) Warren Co., Inc., P.O. Box 1436, Atlanta 1, Ga.
3,C) Weber Showcase & Fixture Co., Inc., P.O. Box 2018, Los Angeles 54, Cal.
3) Wilson Cabinet Co., Inc., Smyrna, Del.

ACKETS, SHELF

ringer Metal Wks., Inc., 108 Jabez St., Newark 5, N.J.
ape & Vogt Mfg. Co., Grand Rapids 4, Mich.
ndard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12

ASS (See particular mill form, i.e., BAR, SHEET, etc.)

AZING

klin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*
zsimons Mfg. Co., 3775 E. Outer Dr., Detroit 12, Mich.
een City Steel Treating Co., 2980 Spring Grove Ave., Cin'ti. 25, O. (Elec. Furnace)

AZING RODS (See WELDING ELECTRODES, RODS & WIRE)

READ COOLERS, BAKERY

nnapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
ans Mfg. Co., 460 S. 10th Ave., Mt. Vernon, N.Y.
y Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
ed D. Pfening Co., 1075 W. 5th Ave., Columbus 8, O.
ad Machinery Div., Standard Stoker Co., York, Pa.
Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
nion Steel Products Co., 448 Pine St., Albion, Mich. *(p. 182)*
ard Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.

REAKER STRIPS

asco Mfg. Co., Harvey, Ill.
ntinental Diamond Fibre Co., 3 Chapel St., Newark, Del.

Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Micarta Fabricators, Inc., 5324 N. Ravenswood Ave., Chicago 40, Ill.
Panelyte Div., St. Regis Paper Co., 230 Park Ave., N.Y.C. 17
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10, Mo.
Rigidized Metals Corp., 658 Ohio St., Buffalo 3, N.Y.
Sandee Mfg. Co., 5050 W. Foster Ave., Chicago 30, Ill.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber)
Swan Rubber Co., Mansfield & Iron Aves., Bucyrus, O.
Amos Thompson Corp., Edinburg, Ind.
Tylac Co., Greeley & High St., Monticello, Ill.

BRINE CIRCULATORS (See AGITATORS)

BRINE COOLERS, DOUBLE TUBE

Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill. (CO_2)
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill
York Corp., York, Pa. *(p. 119)*

BRINE COOLERS, SHELL & COIL

Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 23, N.Y. *(p. 56)*
Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
L. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City 7, N.J.
McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55)*
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Ross Heater & Mfg. Co., Div. of American Radiator & Standard Sanitary Corp., Buffalo 13, N.Y.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Temprite Products Corp., 45 Piquette Ave., Detroit 2, Mich. *(p. 86)*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill. (CO_2)
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119)*

BRINE COOLERS, SHELL & TUBE

Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
American District Steam Co., Bryant St., N. Tonawanda, N.Y.
Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
(Continued)

BRINE COOLERS, SHELL & TUBE (Continued)

Baker Refrigeration Corp., S. Windham, Me. (p. 48)
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Ill.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45)
Davis Engrg. Corp., 1064 E. Grand St., Elizabeth 4, N.J.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. (p. 56)
Frick Co., Waynesboro, Pa. (p. 44)
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Nooter Corp., 1426 S. 2nd St., St. Louis 4. Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. (p. 55)
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. (p. 207)
Reynolds Mfg. Co., Inc., Springfield, Mo.
Richmond Engrg. Co., Inc., 7th & Hospital Sts., Richmond 19, Va.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill. (CO)
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. (p. 119)

BRINE SPRAY UNITS (See UNIT COOLERS)

BRINE TANKS

Arrow Tank Co., Inc., 16 Barnett St., Buffalo 15, N.Y.
Baker Refrigeration Corp., S. Windham, Me. (p. 48)
Biggs Boiler Wks. Co., 1000 Bank St., Akron 5, O.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. (p. 56)
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago 1, Ind.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee 3, Wis.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Pittsburgh-Des Moines Construction Co., Neville Island Pittsburgh 25, Pa.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
Wildman Boiler & Tank Co., 3026 Carroll Ave., Chicago 12, Ill.
York Corp., York, Pa. (p. 119)

BRINE TREATMENT (See also INHIBITORS)

American Sand-Banum Co., Inc., 9 Rockefeller Plaza, N.Y.C. 20
Bello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.
Chemical Solvent Co., Box 487, Birmingham, Ala.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, 4 Ill.
National Aluminate Co., 6216 W. 66th Place, Chicago 38, Ill (p. 221)
North American Fibre Products Co., Standard Bldg., Cleveland 13, O.
O'Brien Industries, 84 Bishop St., Jersey City 4, N.J.
Perolin Co., Inc., 10 E.40th St., N.Y.C. 16
Tempo Chemical Co., 4-88-47th Ave., Long Island City 1, N.Y.

BRONZE (See particular mill form, i.e., BAR, SHEET, etc.)

BRONZE, BEARING STOCK (See BEARING MATERIALS)

BRONZE PARTS (See particular part, also m forms)

BRUSHES, MOTOR & GENERATOR

Bello Industrial Equip. Div., Bogue Elec. Co., 37 K tucky Ave.. Paterson, N.J.
Graphite Metallizing Corp., 1050 Nepperhan Ave., Y kers 3, N.Y.
Keystone Carbon Co., Inc., 1935 State St., St. Marys,
Mutual Chemical Co. of America, 270 Madison A N.Y.C. 16
National Carbon Co., Inc., Unit of Union Carbide & C bon Corp., 30 E. 42nd St., N.Y.C. 17
North American Fibre Products Co., Standard Bl Cleveland 13, O.
Ohio Carbon Co., 12508 Berea Rd., Cleveland 11, O.
Pure Carbon Co., Inc., 445 Hall Ave., St. Marys, Pa.
Speer Carbon Co., St. Marys, Pa.
Superior Carbon Products Co., 9115 George Ave., Cle land 5, O.

BULK ICE MAKERS (See ICE MAKERS, BU TYPE)

BULLETIN BOARDS

Acromark Co., 5 Morrell St., Elizabeth 4, N.J.
Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
Jas. H. Matthews & Co., 3948 Forbes St., Pittsburgh Pa.
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y 17 (p.

BUMPERS, RUBBER (See RUBBER PRODUC MOLDED)

BUS AIR CONDITIONING SYSTEMS

Keco Industries, Inc., Union Trust Bldg., Cin'ti. 2, (
Sterling Mfg. Co., 2523 Farnam St., Omaha, Neb.

BUSHINGS (See particular type; also BEARIN SLEEVE; also FITTINGS, PIPE)

BUSHINGS, FIBRE

Continental Diamond Fibre Co., 3 Chapel St., New Del.
Wilmington Fiber Specialty Co., P.O. Drawer 1028, mington 99, Del.

BUSHINGS, PIPE (See FITTINGS)

BUSHINGS, RUBBER OR RUBBER BONDED

Bushings, Inc., 4358 Coolidge Highway, Royal Oak, M
Firestone Industrial Products Co., 1200 Firestone Pk Akron 17, O.
General Tire & Rubber Co., Garfield St., Wab Ind. (p.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
Lord Mfg. Co. 1635 W. 12th St., Erie, Pa.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic,
Stokes Molded Products, Inc., Taylor At Webster Trenton 4, N.J. (Hard)
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C

BUTANE

Carbide & Carbon Chemicals Corp., Unit of Union bide & Carbon Corp. 30 E. 42nd St., N.Y.C. 17

CABINETS (See listings following, also partic type)

CABINETS, FOR AIR CONDITIONERS

Berger Mfg. Div., Republic Steel Corp., 1038 Belden A N.E., Canton, O.
Bettinger Enamel Corp., Metal Fabricating Div., tham, Mass.
Dahlstrom Metallic Door Co., 435 Buffalo St., Ja town, N.Y
Erie Art Metal Co., 1602 E. 18 St., Erie, Pa.
Falstrom Co., 13 Falstrom Court, Passaic, N.J.

ıtz Mfg. Co., Front St. & Olney Ave., Phila. 20 Pa.
:o Mfg. Co., 49 Ave., W., & Superior St., Duluth 7, Minn.
ysteel Products, Inc., 135 W. Wells St., Milwaukee 3' Wis.
v. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
ublic Steel Corp., Republic Bldg., Cleveland 1, O.
rles Q. Sherman Corp., 149 Broadway, N.Y.C. 6

BINETS, FOR HOUSEHOLD REFRIGERATORS

erican Central Mfg. Corp., Div. of Avco Corp., 18th & Columbia Sts., Connersville, Ind.
napolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
tinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
ans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
go Mfg. Co., 49 Ave., W., & Superior St., Duluth 7, Minn.
ıge Aviation Corp., 102 W. Fowler St., Milwaukee 3, Wis.
x Mfg. Co., Inc., Western Ave., Connersville, Ind.
nitary Refrigerator Co., Fond du Lac, Wis.
ger Refrigerztor Co., 850 Arcade St., St. Paul 6, Minn.
ddard Mfg. Co., 617-4th St., S.W., Mason City, Ia.

BINETS, FREEZING (See HOME & FARM FREEZERS)

BINETS, SEED GERMINATING

P. Pfeiffer & Son, Inc., 200 N. Paca St., Baltimore 1, Md.

BINET PARTS (See also particular part)

hringer Metal Wks., Inc., 108 Jabez St., Newark 5, N.J.
ttinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
andal-Stone Div., Brewer-Titchener Corp., 336 Court St., Binghamton, N.Y.
ahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
etroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
eintz Mfg. Co., Front St. & Olney Ave., Phila. 20, Pa.
ent Plastics, 1528 N. Fulton Ave., Evansville, Ind.
ndsay Structure, Inc., 1740-25th Ave., Melrose Park, Ill.
ack Molding Co., Ryerson Ave., Wayne, N.J.
aysteel Products, Inc., 135 W. Wells St., Milwaukee 3, Wis.
etal Specialty Co., Este Ave. & B&O R.R., Cin'ti., O.
remium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
andee Mfg. Co., 5050 W. Foster Ave., Chicago 30, Ill.
epublic Steel Corp., Republic Bldg., Cleveland 1, O.
harles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
tanley Wks., 195 Lake St., New Britnai, Ct.
mos Thompson Corp., Edinburg, Ind.
. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.

ABINET TOPS & LIDS

merican Hard Rubber Co., 11 Mercer St., N.Y.C. 13
astian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
ettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
ryden Rubber Co., 1014 S. Kildare Ave., Chicago 24, Ill.
ormica Co., 4613 Spring Grove Ave., Cincinnati 32, O.
. F. Goodrich Co., 500 S. Main St., Akron, O.
ordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
uzerne Rubber Co., Trenton 9, N.J.
anelyte Div., St. Regis Paper Co., 230 Park Ave., N.Y.C. 17
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J.
Thermacote Co., 420 S. San Pedro St., Los Angeles 13, Cal.

CABLE, ELECTRIC (See also WIRE, ELECTRIC)

American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Federal Telephone & Radio Corp., 900 Passaic Ave., E. Newark, N.J.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
National Elec. Products Corp., Fulton Bldg., Pittsburgh 22, Pa.
Packard Elec. Div., Gen'l. Motors Corp., Warren, O.
Pent Elec. Co., Inc., 634 Michigan Trust Bldg., Grand Rapids 2, Mich.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

CALCIUM CHLORIDE

Barada & Page, Inc., Guinotte & Michigan Aves., Kansas City 1, Mo.
Henry Bower Chemical Mfg. Co., Gray's Ferry Rd. & 29th St., Phila. 46, Pa.
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.
Columbia Chemical Div., Pittsburgh Plate Glass Co., 5th Ave. at Bellefield, Pittsburgh 13, Pa.
Dow Chemical Co., Midland, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Michigan Alkali Div., Wyandotte Chemicals Corp., Wyandotte, Mich.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Phila. 7, Pa.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Solvay Sales Div., Allied Chemical & Dye Corp., 40 Rector St., N.Y.C. 6
Tamms Industries, 228 N. La Salle St., Chicago 1, Ill.

CALCIUM SULFATE, ANHYDROUS (See DEHYDRANTS)

CAN FILLERS (See ICE MANUFACTURING ACCESSORIES)

CANDY CASES, REFRIGERATED

Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
C. F. Moores Co., Inc., 1133 Ivy Hill Rd., Wyndmoor, Phila. 18, Pa.

CANS, ICE (See ICE CANS)

CANVAS & DUCK & SPECIALTIES

Canvas Products Co., 1236 S. 7th St., St. Louis 4, Mo.
Flexible Tubing Corp., N. Main St., Branford, Ct.
Lehon Co., 4425 S. Oakley Ave., Chicago 9, Ill.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Wagner Awning & Mfg. Co., 2658 Scranton Rd., Cleveland 1, O.
Webb Mfg. Co., 4th & Cambria Sts., Phila. 33, Pa.

CAPACITORS, ELECTRICAL

Aerovox Corp., New Bedford, Mass.
Cornell-Dubillier Elec. Corp., S. Plainfield, N.J.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
P. R. Mallory & Co., Inc., 3029 E. Washington St. Indpls., Ind.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Sprague Products Co., Marshall St., N. Adams, Mass.
Tobe Deutschman Corp., 921 Providence Pike, Norwood, Mass.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

CAPS, WELDING (See FITTINGS, WELDING)

CARBON DIOXIDE (See also DRY ICE)

Air Reduction Sales Co., 60 E. 42nd St., N.Y.C. 17
Liquid Carbonic Corp., 3100 S. Kedzie Ave., Chicago 23, Ill.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
Pure Carbonic, Inc., 60 E. 42nd St., New York, 17, N.Y.

CARBON DIOXIDE ACCESSORIES

Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.

CARBON PRODUCTS (See also GRAPHITE PRODUCTS; also BRUSHES)

Ohio Carbon Co., 12508 Berea Rd., Cleveland 11, O.
Pure Carbon Co., Inc., 445 Hall Ave., St. Marys, Pa.
Speer Carbon Co., St. Marys, Pa.

CARBONATORS & CARBONATING EQUIPMENT

Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Hudson Products Co., Inc., 4400 St. Aubin, Detroit 7, Mich.
Liquid Carbonic Corp., 3100 S. Kezdie Ave., Chicago 23, Ill.
Mojonnier Bros. Co., 4601 W. Ohio St., Chicago, Ill.
Paley Mfg. Corp., 244 Herkimer St., Brooklyn 16, N.Y.
Scientific Research Co., 1618 N. Vancouver, Portland 12, Ore.
Spacarb, Inc., 311 E. 23rd St., N.Y.C. 10
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*

CARTS, MATERIAL HANDLING (See TRUCKS)

CASTINGS, ALUMINUM

Aluminum Co. of America, Pittsburgh 19, Pa.
Aluminum Industries, Inc., 2438 Beekman St., Cin'ti. 25, O.
Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
Bohn Aluminum & Brass Corp., E. Maumee, Adrian, Mich.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Heat-X-Changer Co., Inc., 415 Lexington Ave.) N.Y.C. 17 *(p. 122,*
Paxton-Mitchell Co., 2614 Martha St., Omaha 5, Neb.
Permold Co., W. Liberty St., Medina, O.
Universal Foundry Co., 86 Pine St., Oshkosh, Wis.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.

CASTINGS, BRASS, BRONZE, etc.

Aluminum Industries, Inc., 2438 Beekman St., Cin'ti. 25, O.
Bearium Metals Corp., 268 State St., Rochester, N.Y.
Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
Bethlehem Steel Co., Bethlehem, Pa.
Bohn Aluminum & Brass Corp., E. Maumee, Adrian, Mich.
Bunting Brass & Bronze Co., 715 Spencer St., Toledo 9, O.
Connecticut Precision Casting Co., New Canaan, Ct.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Arthur Harris & Co., 210 N. Aberdeen St., Chicago 7, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Hills-McCanna Co., 3029 N. Western Ave., Chicago 18, Ill.
Hooven, Owens, Rentschler Div., General Machinery Corp., 545 N. 3rd St., Hamilton, O.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
Manistee Iron Wks. Co., River St., Manistee, Mich.
Mueller Brass Co., Port Huron, Mich.
National Lead Co., 111 Broadway, N.Y.C. 6
Newman Bros., Inc., 666 W. 4th St., Cin'ti. 3, O.
Niles Tool Wks. Div., General Machinery Corp., 545 N. 3rd St., Hamilton, O.
Paxton-Mitchell Co., 2614 Martha St., Omaha 5, Neb.
Universal Foundry Co., 86 Pine St., Oshkosh, Wis.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.
York Corp., York, Pa. *(p. 119)*
J. A. Zurn Mfg. Co., Erie, Pa

CASTINGS, DIE

AC Spark Plug Div., Gen'l. Motors Corp., Flint 2, Mich.
Aluminum Industries, Inc., 2438 Beekman St., Cin'ti. 25, O.
Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
Chicago Expansion Bolt Co., 1338 W. Concord Place, Chicago 22, Ill.
Doehler-Jarvis Corp., 386-4th Ave., N.Y.C. 16
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Grand Rapids Brass Co., 60 Scribner Ave., N.W., Grand Rapids 1, Mich.
National Lock Co., 7th St. & 18th Ave., Rockfor Ill. *(p. 1*
Sterling Die Casting Co., Inc., 743-39th St., Brookl 32, N.Y.
Titan Metal Mfg. Co., Bellefonte, Pa.
York Corp., York, Pa. *(p. 1*

CASTINGS, LEAD

Belmont Smelting & Refining Wks., 330 Belmont Av Brooklyn 7, N.Y.
Chicago Expansion Bolt Co., 1338 W. Concord Place, Ch cago 22, Ill.
National Lead Co., 111 Broadway, N.Y.C. 6

CASTINGS, MONEL; NICKEL & NICKEL ALLO

Cooper Alloy Foundry Co., Bloy St. & Ramsey Ave., Hi side 5, N.J.
Haynes Stellite Co., Unit of Union Carbide & Carb Corp., Kokomo, Ind.
International Nickel Co., 67 Wall St., N.Y.C. 5
Ohio Steel Foundry Co., James St., Springfield, O.
Ross-Mehan Foundries, Chattanooga, Tenn.

CASTINGS, STEEL & IRON

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsbur 22, Pa.
Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Bethlehem Steel Co., Bethlehem, Pa.
Bonney-Floyd Co., 611 Marion Rd., Columbus, O.
Cooper-Bessemer Corp., Mt. Vernon, O.
Dayton Malleable Iron Co., P.O. Box 980, Dayton 1,
Eaton Mfg. Co., 9771 French Rd., Detroit 33, Mich.
Benjamin Eastwood Co., 300 Straight St., Paterson, N
Frick Co., Waynesboro, Pa. *(p. 4*
Grinnell Co., Inc., 260 W. Exchange St., Providence R.I.
Haynes Stellite Co., Unit of Union Carbide & Carb Corp., Kokomo, Ind.
Hooven, Owens, Rentschler Div., General Machine Corp., 545 N. 3rd St., Hamilton, O.
Jeffrey Mfg. Co., 887 N. 4th St., Columbus 16, O.
Lakeside Malleable Castings Co., Racine, Wis.
Link-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind.
P. H. MaGirl Foundry & Furnace Wks., 413 E. Oakla Ave., Bloomington, Ill.
National Malleable & Steel Castings Co., 10600 Quin Ave., Cleveland 6, O.
Niles Tool Wks. Div., General Machinery Corp., 545 3rd St., Hamilton, O.
Ohio Steel Foundry Co., James St., Springfield 1, R.I.
Paxton-Mitchell Co., 2614 Martha St., Omaha 5, Neb.
Pyott Foundry & Machine Co., 328 N. Sangamon St., C cago 7, Ill.
Ross-Mehan Foundries, Chattanooga, Tenn.
Saginaw Malleable Iron Div., Gen'l. Motors Corp., Sa naw, Mich.
Shenango-Penn Mold Co., Dover, O.
Union Mfg. Co., New Britain, Ct.
Universal Foundry Co., 86 Pine St., Oshkosh, Wis.
Vilter Mfg. Co., 2223 S. 1st St., Milwaukee 7, Wis *(p.*
York Corp., York, Pa. *(p. 1*
J. A. Zurn Mfg. Co., Erie, Pa.

CEMENT, INSULATION (See also INSULATIO ERECTION MATERIALS)

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
Atlas Asbestos Co., Ltd., 110 McGill St., Montreal Quebec, Canada
Carney Co., Inc., 125 S. 5th St., Minneapolis 2, Minn.
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 1*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Owens-Corning Fiberglas Corp., 2012 Nichol Bldg., Toledo 1, O. *(p. 1*
Refractory & Insulation Corp., 120]] Wa St., N.Y.C. 5
Robinson Insulation Co., Great Falls, Mont.
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Taft-Jenkins Co., Inc., 27 Sargeant St., Holyoke, Mas
Universal Zonolite Insulation Co., 135 S. La Salle St., C cago 3, Ill.
Grant Wilson, Inc., 316 S. La Salle St., Chicago 4, Ill.
Virginia Smelting Co., W. Norfolk, Va. *(p. 1*

MENTS, RUBBER, SYNTHETIC, etc. (See also ADHESIVES; also COMPOUNDS)

ise Industrial Refrigerator Equip. & Engrg. Co., 630 Reading Rd., Reading, O.
I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
estone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
njamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.
F. Goodrich Co., 500 S. Main St., Akron, O.
ear, Inc., State Rd. & Levick St., Phila. 35, Pa.
nnesota Mining & Mfg. Co., 900 Fauquier St., St. Paul 6, Minn.
racle Adhesives Corp., 214 E. 53rd St., N.Y.C. 22
odloe E. Moore Co., 2811 N. Vermilion, Danville, Ill.
tsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
ndolph Products Co., Carlstadt, N.J. *(p. 101)*
ic-Klip Mfg. Co., 50 Regent St., Cambridge 40, Mass. *(p. 127)*
S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
n Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.
rginia Smelting Co., W. Norfolk, Va. *(p. 168)*
ant Wilson, Inc., 316 S. La Salle St., Chicago 4, Ill.

IAIN, CONVEYOR, DRIVE, ROLLER, etc.

vey-Ferguson Co., Disney & R Sts., Cin'ti. 9, O.
ldwin Duckworth Div., Chain Belt Co., 369 Plainfield St., Springfield, Mass.
nveyor Co., 3260 E. Slauson Ave., Los Angeles 11, Cal.
rbin Screw Corp., New Britain, Ct.
clone Fence Div., American Steel & Wire Co., U. S. Steel Corp. Subsidiary, P.O. Box 260, Waukegan 1, Ill.
amond Chain Co., Inc., 402 Kentucky Ave., Indpls. 7, Ind.
art & Cooley Mfg. Co., 500 E. 8th St., Holland, Mich.
ffrey Mfg. Co., 887 N. 4th St., Columbus 16, O.
nk-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind.
orse Chain Co., Div. of Borg-Warner Corp., Ithaca, N.Y.
amsey Chain Co., Inc., 900 Broadway, Albany 1, N.Y.
monds Gear & Mfg. Co., 2501 Liberty Ave., Pittsburgh 22, Pa.
ransue & Williams Steel Forging Corp., Alliance, O.
nited Engine Co., W. Holmes Rd., Lansing 12, Mich.
atson Flagg Machine Co., 845 E. 25th St., Paterson 3, N.J.

HANNELS (See SHAPES, STRUCTURAL)

HARGING LINES (See also FLEXIBLE CONNECTIONS; also TUBING, FLEXIBLE)

eroquip Corp., 300 S. East Ave., Jackson, Mich.
merican Brass Co., Waterbury 88, Ct. *(p. 199)*
hicago Metal Hose Corp., Maywood, Ill.
ine Products Co., 185 N. Wabash Ave., Chicago 1, Ill.
lexible Tubing Corp., N. Main St., Branford, Ct.
enry Valve Co., Melrose Park, Ill. *(p. 84)*
mperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
ohnson Metal Hose Co., 226 Mill St., Waterbury 88, Ct.
ladden Brass Products Co., 1111 N. Franklin St., Chicago 10, Ill.
aybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
esistoflex Corp., 39 Plansoen St., Belleville 9, N.J.
eamlex Co., Inc., 4123-24th St., Long Island City 1, N.Y.
uperior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 85)*
Vabash Mfg. Co., 2300 S. Western Ave., Chicago 8, Ill.
Veatherhead Co., 300 E. 131st St., Cleveland 8, O.
York Corp., York, Pa. *(p. 119)*

HECK VALVES, AIR, WATER

utomatic Temperature Control Co., Inc., 5212 Pulaski Rd., Phila. 44, Pa.
hase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
ames B. Clow & Son, 201 N. Talman Ave., Chicago 12, Ill.
onoflow Corp., 2100 Arch St., Phila. 28, Pa.
rane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Darling Valve & Mfg. Co., Foot Walnut St., Williamsport, Pa.
Defender Instrument & Regulator Co., 815 Clark Ave. St. Louis 2, Mo.
R. & J. Dick Co., Inc., 24 Sade St., Passaic, N.J.
Durabla Mfg. Co., 114 Liberty St., N.Y.C. 6
Edward Valves, Inc., Subsidiary of Rockwell Mfg. Co., 1200 W. 145 St., E. Chicago, Ind.
Fairbanks Co., 393 Lafayette, N.Y.C. 3
Gas & Oil Industry Labs., Inc., 4 Paine Ave., Irvington 11, N.J.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Grove Regulator Co., 6529 Hollis St., Oakland, Cal.
Hancock Valve Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Hydrovalve Co., 262 W. 38th St., N.Y.C. 18
Jarecki Mfg. Co., 1345 W. 12th St., Erie, Pa.
Kennedy Valve Mfg. Co., Elmira, N.Y.
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Ludlow Valve Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Lunkenheimer Co., Beekman St., & Waverly Ave., Cin'ti. 14, O.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Manning, Maxwell & Moore, Inc., Watertown 72, Mass.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.
Swaby Mfg. Co., 3818 W. Armitage Ave., Chicago 47, Ill.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
J. A. Zurn Mfg. Co., Erie, Pa.

CHECK VALVES, REFRIGERANT
(A—Ammonia; B—Other refrigerants)

(B) Automatic Products Co., 2450 N. 32nd St., Milwaukee 10. Wis. *(p. 96)*
(A,B) Baker Ice MRefrigeration Corp., S. Windham, Me. *(p. 48)*
(A,B) Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
(A) Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
(A) Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
(A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
(A,B) Henry Valve Co., Melrose Park, Ill. *(p. 84)*
(A,B) Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
(B) Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
(B) Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Madden Brass Products Co., 1111 N. Franklin St., Chicago 10, Ill.
(B) Mueller Brass Co., Port Huron, Mich.
(B) Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 85)*
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(A) Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
(A,B) Watson-Stillman Co., Roselle, N.J. *(p. 109)*
(B) Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
(A,B) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
(A) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,B) York Corp., York, Pa. *(p. 119)*
J. A. Zurn Mfg. Co., Erie, Pa.

CHILLERS, CONTINUOUS

Votator Div., Girdler Corp., Louisville 1, Ky.

CIRCUIT BREAKERS

Allen-Bradley Co., Milwaukee 4, Wis.
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

(Continued)

CIRCUIT BREAKERS (Continued)

Bello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
Fasco Industries, Inc., Union & Augusta Sts., Rochester 2, N.Y.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
I.T.E. Circuit Breaker Co., 19th & Hamilton St., Phila., Pa.
Trumbull Elec. Mfg. Co., 999 Woodford Ave., Plainville, Ct.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

CIRCULATORS, AIR (See FANS)

CLAMPS, CONDUIT, CABLE, PIPE, TUBING, etc. (See also HANGERS, PIPE)

General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Marman Products Co., Inc., 940 Redondo, Inglewood, Cal
Minerallac Elec. Co., 25 N. Peoria St., Chicago 7, Ill.
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Prestole Corp., 1345 Miami St., Toledo, O.
M. B. Skinner & Co., South Bend 23, Ind. *(p. 104)*
Tinnerman Products, Inc., 2038 Fulton Rd., Cleveland 13, O.
Trico Fuse Mfg. Co., 2948 N. 5th St., Milwaukee 12, Wis.
U. S. Expansion Bolt Co., York, Pa.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.

CLIPS (See FASTENERS; also SUPPORTS)

CLOCKS

Ashcroft Gauge Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Elgin Nat'l. Watch Co., 103 National St., Elgin, Ill.
General Elec. Co., 1285 Boston Ave., Bridgeport 2, Ct.
Marshalltown Mfg. Co., Marshalltown, Ia.

CLOSERS, COLD STORAGE DOOR

Chase Industrial Refrigerator Equip. & Engrg. Co., 630 Reading Rd., Reading, O.
Chicago Spring Hinge Co., 1500 Carroll Ave., Chicago 7, Ill.
Jamison Cold Storage Door Co., Hagerstown, Md.
Kason Hardware Corp., 127 Wallabout St., Brooklyn 6, N.Y.
Streator Products Corp., 508 N. 8th St., Fairfield, Ia.
York Corp., York, Pa. *(p. 119)*

CLOTH, WIRE (See MESH, METAL; also WIRE CLOTH)

CLUTCHES

Black-Clawson Co., Middletown, O.
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
Dodge Mfg. Corp., 505 S. Union St., Mishawaka, Ind.
Hilliard Corp., 102 W. 4th St., Elmira, N.Y.
W. A. Jones Foundry & Machine Co., 4401 Roosevelt Rd., Chicago 24, Ill.
Link-Belt Co., 300 Pershing Rd., Chicago 9, Ill.
Mercury Clutch Div., Automatic Steel Products, Inc., 1201 Camden Ave., Canton 6, O.
Morse Chain Co., Div. of Borg-Warner Corp., Ithaca, N.Y.
Salisbury Motor Div., Wayne Mfg. Co., 1201 Lexington Ave., Pomona, Cal.
Twin Disc Clutch Co., Racine, Wis.
V-Belt Clutch Co., 418 N. Western Ave., Los Angeles 4, Cal.
Watson Flagg Machine Co., 845 E. 25th St., Paterson 3, N.J.

COATINGS & COMPOUNDS, PROTECTIVE, PLASTIC, etc. (See also FINISHES)

American Chemical Paint Co., Ambler, Pa.
American Pipe & Construction Co., Box 3428 Terminal Annex, Los Angeles 54, Cal.
Bonafide Genasco, Inc., 295-5th Ave., N.Y.C. 16
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Chemical Solvent Co., Box 487, Birmingham, Ala.
Dampney Co. of America, Hyde Park, Boston 36, Mas
Dennis Chemical Co., 2701 Papin St., St. Louis 3, Mo.
Dow Chemical Co., Midland, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington 9 Del.
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
Ernecke & Salmstein Co., 1611 N. Sheffield Ave., Chicag 14, Ill.
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, P
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Grand Rapids Varnish Corp., 1350 Steele Ave S.W Grand Rapids 2, Mich.
Haynes Stellite Co., Unit of Union Carbide & Carbo Corp., Kokomo, Ind.
A. C. Horn Co., Inc., 43-36-10th St., Long Island Cit N.Y.
Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N.
Master Mechanics Co., Freeman Rd., Cleveland 13, O.
Miracle Adhesives Corp., 214 E. 53rd St., N.Y.C. 22
B. F. Nelson Mfg. Co., 401 Main St., N.E., Minneapol 13, Minn.
Nox-Rust Chemical Corp., 2429 S. Halsted St., Chicago Ill.
Oakite Products, Inc., 22 Thames St., N.Y.C. 6
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburg 22, Pa.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 1 Mo.
Quigley Co., Inc., 427-5th Ave., N.Y.C. 17
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Sherwin-Williams Co., 101 Prospect Ave., N.W., Clev land, O.
L. Sonneborn Sons, Inc., 88 Lexington Ave., N.Y.C. 1
Steelcote Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo
Tuco Products Corp., 30 Church St., N.Y.C. 7
United Chromium, Inc., 51 E. 42nd St., N.Y.C. 17
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C.
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago Ill.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.
Wailes Dove-Hermiston Corp., 448 South Ave., Westfiel N.J.
Western Chemical Co., 713 Washington St., Kansas Ci 6, Mo.
Wilbur-Williams Co., 43 Leon St., Boston, Mass.
X-Pando Corp., 43-15-36th St., Long Island City 1, N.

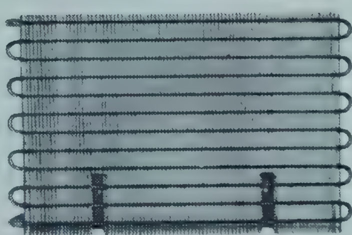
COCKS

Ashton Valve Co., 161-1st St., Cambridge 42, Mass.
L. J. Bordo Co., Inc., 115 New St., Glenside, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p 10*
Fairbanks Co., 393 Lafayette, N.Y.C. 3
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin' 14, O.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque,
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Swift Lubricator Co., Inc., 101 Home St., Elmira, N.Y
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Wright-Austin Co., 315 W. Woodbridge St., Detroit 2 Mich.

COIL & BAFFLE ASSEMBLIES (A—Ammonia; B—Other refrigerants)

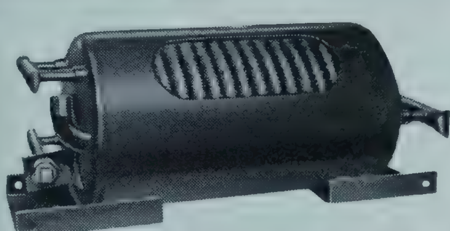
American Coils Co., 25 Lexington St., Newark 5, N.J.
(A,B) Baker Refrigeration Corp., S. Windham, Me *(p.*
(A,B) Bush Mfg. Co., 179 South St., W. Hartford Ct. *(p. 2*
Cold Control, Inc., 111 Broadway, N.Y.C. 6
(A,B) Gay Engrg. Co., 2730 E. 11th St., Los Angeles Cal.
(B) Hussmann Refrigeration, Inc., 2401 N. Leffin well, St. Louis 6, Mo. *(p.*
(B) Kramer Trenton Co., Olden & Breuning Ave Trenton 5, N.J. *(p.*
(A,B) Larkin Coils, 519 Memorial Dr., S.E., Atlan 1, Ga. *(p.*
(B) McCord Corp., Riopelle & E. Grand Blvd., D troit 11, Mich. *(p.*
(A,B) McQuay, Inc., 1600 Broadway, N.E., Mi neapolis 13, Minn. *(p. 9*
(B) Melco Mfg. Co., Inc., Grand Ave., Ridgefield, N.
(Continue

McCORD Refrigeration and Air Conditioning Products



CONTINUOUS TUBE DOMESTIC CONDENSER

Round continuous tube, plate or fin type condensers for domestic refrigeration.



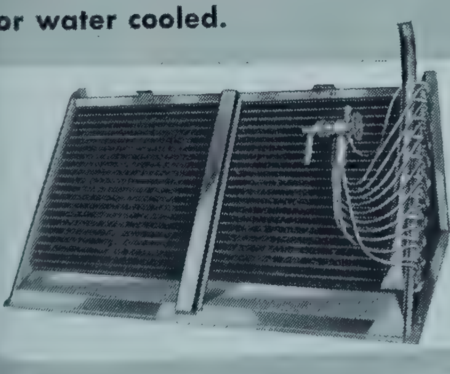
WATER COOLED CONDENSER

Condensers for commercial refrigeration and air conditioning, air or water cooled.

BACKED BY 42 YEARS of Heat Transfer Experience

A pioneer in the Heat Transfer Industry, many outstanding developments have come from McCord laboratories. Both spiral and extended fin surfaces are developments of McCord. McCord surfaces are designed to meet all heat transfer requirements at a minimum of cost. Positive contacts insure permanency of rated heat transfer capacity. Maintain your reputation by specifying McCord-engineered heat transfer surface.

McCORD CORPORATION
Detroit 11, Michigan



AIR CONDITIONING EVAPORATOR

Evaporator coils for air conditioning, engineered to meet your heat transfer requirements.

COIL & BAFFLE ASSEMBLIES (Continued)

A. B. Murray Co., Inc., 604 Green Lane, Elizabeth, N.J.
(A,B) National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
(A,B) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(A) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(B) Reese & Long Refrigeration Products, Inc., 408 E. 25th St., N.Y.C. 10
Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B) Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
(B) Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(A,B) Swan Engrg. Co., Inc., 22 Nelson St., Bloomfield, N.J.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(A,B) Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
(A,B) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
(A,B) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

COIL STOCK (See STRIP)

COILS (See particular type, i.e., FINNED COILS; PLATE COILS; UNIT COOLERS; etc.)

COILS, SPECIAL
(A—Ammonia; B—Other refrigerants)

(A,B) Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
(A,B) Aerofin Corp., 410 Geddes St., Syracuse, N.Y. *(p. 15)*

(A,B) Baker Refrigeration Corp. Inc., S. Windham, Me. *(p. 4*
(A,B) Bush Mfg. Co., 179 South St., W. Hartford 1, Ct. *(p. 20*
(B) Crandal-Stone Div., Brewer-Titchener Corp., 3 Court St., Binghamton, N.Y.
(A,B) Crane Co., 836 Michgan Ave., Chicago 5, Ill. *(p. 10*
Dersch, Gesswein & Neuert, Inc., 4845 W. Gran Ave., Chicago 39, Ill. *(p. 19*
(A,B) Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 5*
(A,B) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(A,B) Frick Co., Waynesboro, Pa. *(p. 4*
(A,B) Gay Engrg. Co., 2730 E. 11th St., Los Angeles 2 Cal.
(A,B) General Refrigeration Div., Yates-America Machine Co., Beloit, Wis. *(p. 5*
(A,B) Howe Ice Machine Co., 2825 Montrose Ave Chicago 18, Ill. *(p. 20*
(B) Hussmann Refrigerator Co., 2401 N. Leffing well, St. Louis 6, Mo. *(p. 8*
(B) Kramer Trenton Co., Olden & Breuning Aves Trenton 5, N.J. *(p. 20*
(A,B) Larkin Coils, 519 Memorial Dr., S.E., Atlant 1, Ga. *(p. 20*
(B) Long Mfg. Div., Borg-Warner Corp., 12501 Dequi dre St., Detroit 12, Mich.
(B) McCord Corp., Riopelle & E. Grand Blvd., De troit 11, Mich. *(p. 3*
(A,B) McQuay, Inc., 1600 Broadway, N.E., Mi neapolis 13, Minn. *(p. 20*
(A,B) Marlo Coil Co., 6135 Manchester Ave., S Louis 10, Mo. *(p. 20*
(B) Melco Mfg. Co., Inc., Grand Ave., Ridgefield, N.J
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.
National Pipe Bending Co., 110 River St., New Haven 1 Ct.
(A,B) National Refrigerators Co., 827 Koeln Ave., S Louis 11, Mo.
(A,B) Niagara Blower Co., 405 Lexington Ave N.Y.C. 17 *(p. 9*
(A) Nooter Corp., 1426 S. 2nd St., St.Louis 4, Mo.
(B) Paley Mfg. Corp., 244 Herkimer St., Brooklyn 1 N.Y.
(A) Pittsburgh Pipe Coil & Bending Co., 61 Bridge S Etna P.O., Pittsburgh 23, Pa.
(A,B) Reco Products Div., Refrigeration Engrg. Corp 2020 Naudain St., Phila. 46, Pa.
(B) Reese & Long Refrigeration Products, Inc., 408 25th St., N.Y.C. 10
(A,B) Refrigeration Appliances, Inc., 917 W. Lake S Chicago 7, Ill.
(A,B) Refrigeration Economics Co., Inc., 1231 Tuscarawas St., Canton 4, O. *(p. 2*
(A,B) Refrigeration Engrg., Inc., 7250 E. Slaus Ave., Los Angeles, Cal. *(p. 2*
(A,B) Reliance Refrigerating Machine Co., 3401 N. Ke zie Ave., Chicago 18, Ill.
(A,B) Rempe Co., 340 N. Sacramento Blvd., Chicago 1 Ill.
Edw. Renneburg & Sons So., 2639 Boston St., Baltimo 24, Md.
(A,B) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, I
(A) Roessing Mfg. Co., Sharpsburg Sta., Pittsburgh, F
(B) Rome-Turney Radiator Co., Rome, N.Y. *(p. 9*
(A,B) St. Louis Blow Pipe & Heater Co., Inc., Div. Skinner Heating & Ventilating Co., Inc., 1948 9th St., St. Louis 6, Mo.
John Simons Co., Inc., 50 Church St., N.Y.C. 7
(A,B) Stewart Ice Machine Co., 1282 W. 1st St., Pomona Cal.
(B) Super-Cold Corp., 1020 E. 59th St., Los Angeles Cal.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee Wis. *(p. 4*
(A) Henry Vogt Machine Co., 10th & Ormsby St., Lou ville 10, Ky.
(A,B) Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
(A,B) Worthington Pump & Machinery Corp., Ha rison, N.J. *(p.*
(A) XL Refrigerating Co., 1834 W. 59th St., Chicago Ill.
(A,B) York Corp., York, Pa. *(p.*
Young Radiator Co., Racine, Wis. *(p.*

COLD CONTROLS (See THERMOSTATS)

COLD STORAGE DOORS & WINDOWS

Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*

Butcher Boy Cold Storage Door Co., 170 N. Sangamon St., Chicago 7, Ill. *(p. 41)*

Chase Industrial Refrigerator Equip. & Engrg. Co., 630 Reading Rd., Reading, O.

Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17

Cruse Refrigerator Co., Inc., 504 Main St., Louisville 2, Ky.

Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, Pa.

Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.

Fleetwood-Airflow, Inc., 421 N. Penna Ave., Wilkes-Barre, Pa.

Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.

John Herrel & Sons Co., 244 Lear St., Columbus 6, O.

Jamison Cold Storage Door Co., Hagerstown, Md.

Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.

Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.

Jack Langston Co., 3700 Elm St., Dallas 1, Tex.

Lingle Refrigerator Co., Inc., 1116 E. 15th St., Kansas City 6, Mo.

Masterfreeze Corp., Sister Bay, Wis.

Matthews Refrigerator & Door Co., 5103 S.E. Powell Blvd., Portland 6, Ore.

John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.

National Refrigerators Co., 827 Koeln Ave., St. Louis 11' Mo.

Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.

Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*

C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.

Schwenger-Klein, Inc., 720 Bolivar Rd., Cleveland, O.

Streator Products Corp., 508 N. 8th St., Fairfield, Ia.

Sub Zero, Inc., 41 E. 42nd St., N.Y.C. 17

Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.

York Corp., York, Pa. *(p. 119)*

COLD STORAGE DOOR HARDWARE (See HARDWARE, COLD STORAGE DOOR; also CLOSERS)

COLLARS, SHAFT

Chicago Die Casting Mfg. Co.; 2500 W. Monroe St., Chicago 12, Ill.

Link-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind.

COLUMNS, WATER (See GAUGE GLASSES)

COMPOUNDS, CAULKING

Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.

Calbar Paint & Varnish Co., 2612 N. Martha St., Phila. 25, Pa.

Chamberlin Co. of America, 1254 LaBrosse St., Detroit 26, Mich.

Jesse G. Croll & Son, 2606 Germantown Ave., Phila. 33, Pa.

Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.

Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.

B. F. Goodrich Co., 500 S. Main St., Akron, O.

Lexington Supply Co., 4815 Lexington Ave., Cleveland 3, O.

Master Mechanics Co., Freeman Rd., Cleveland 13, O.

Nebell Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.

B. F. Nelson Mfg. Co., 401 Main St., N.E., Minneapolis 13, Minn.

Pecora Paint Co., Inc., 3rd & Lawrence Sts., Phila. 40, Pa.

Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.

Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10, Mo.

H. H. Robertson Co., 2400 Farmers Bank Bldg., Pittsburgh 22, Pa.

L. Sonneborn Sons, Inc., 88 Lexington Ave., N.Y.C. 16

Steelcote Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo.

Tamms Industries, Inc., 228 N. La Salle St., Chicago 1, Ill.

Virginia Smelting Co., W. Norfolk, Va. *(p. 168)*

Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.

Western Chemical Co., 713 Washington St., Kansas City 6, Mo.

X-Pando Corp., 43-15-36th St., Long Island City 1, N.Y.

COMPOUNDS, CORROSION INHIBITING (See BRINE TREATMENT; also INHIBITORS, CORROSION; also WATER TREATING)

COMPOUNDS, GASKET, PIPE JOINT, etc.

Arco Co., 7301 Bessemer Ave., Cleveland 4, O.

Calbar Paint & Varnish Co., 2612 N. Martha St., Phila 25, Pa.

Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.

Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*

Crane Packing Co,. 1800 Cuyler Ave., Chicago 13, Ill.

Jesse G. Croll & Son, 2606 Germantown Ave., Phila. 33 Pa.

Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.

Galv-Weld Products, 324 E. 2nd St., Dayton 2, O.

Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.

Goetze Branch, Johns-Manville Products Corp., Allen Ave., New Brunswick, N.J.

B. F. Goodrich Co., 500 S. Main St., Akron, O.

Grinnell Co., Inc., 260 W. Exchange St., Providence 1 R.I.

A. C. Horn Co., Inc., 43-36-10th St., Long Island City N.Y.

Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22 Pa. *(p. 213)*

Keystone Lubricating Co., 21st & Lippincott St., Phila 32, Pa.

Lake Chemical Co., 3052 W. Carroll Ave., Chicago 12, Il

Macksons Co., 127 Cedar St., N.Y.C. 6

Minnesota Mining & Mfg. Co., 900 Fauquier St., St. Pau 6, Minn.

Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.

Parker Appliance Co., 17325 Euclid Ave., Cleveland 12 O.

Pecora Paint Co., Inc., 3rd & Lawrence Sts., Phila. 40, Pa

Permatex Co., Inc., 1720 Ave. Y, Brooklyn 29, N.Y.

Presstite Engrg. Co., 2900 Chouteau Ave., St. Louis 10 Mo.

Quigley Co., Inc., 527-5th Ave., N.Y.C. 17

H. H. Robertson Co., 2400 Farmers Bank Bldg., Pitts burgh 22, Pa.

Rutland Fire Clay Co., Curtis Ave., Rutland, Vt.

Smooth-On Mfg. Co., 572 Communipaw Ave., Jersey Cit 4, N.J.

Tempo Chemical Co., Inc., 4-88-47th Ave., Long Islan City 1, N.Y.

Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicag 19, Ill.

Virginia Smelting Co., W. Norfolk, Va. *(p. 16*

J. C. Whitlam Mfg. Co., Wadsworth, O.

X-Pando Corp., 43-15-36th St., Long Island City 1, N.Y

COMPOUNDS, MASTIC

American Bitumuls Co., 200 Bush St., San Francisco 4 Cal.

Amercoat Div., American Pipe & Construction Co., 480 Firestone Blvd., South Gate, Cal.

Arco Co., 7301 Bessemer Ave., Cleveland 4, O.

Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.

Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17

Ehret Magnesia Mfg. Co., Valley Forge, Pa.

Flint Kote Co., East Rutherford, N.J.

Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa

Lehon Co., 4425 S. Oakley Ave., Chicago 9, Ill.

Lewis Asphalt Engrg. Corp., 30 Church St., N.Y.C.

Lexington Supply Co., 4815 Lexington Ave., Cleveland 3 O.

Minnesota Mining & Mfg. Co., 900 Fauquier St., St. Pa 6, Minn.

Goodloe E. Moore Co., 2811 N. Vermilion, Danville, Il

Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.

Pecora Paint Co., Inc., 3rd & Lawrence Sts., Phila. 40, Pa

Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10 Mo.

Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C 17 *(p. 13*

Virginia Smelting Co., W. Norfolk, Va. *(p. 16*

COMPOUNDS, WATERPROOFING

Amercoat Div., American Pipe & Construction Co., 48 Firestone Blvd., South Gate, Cal.

American Bitumuls Co., 200 Bush St., San Francisco Cal.

(Continued

"Butcher Boy" COLD STORAGE DOORS

Since 1885

This "Butcher Boy" standard type cold storage door is equipped with "Super-Seal" fasteners and "Finger-Tip" Door Openers for greatest efficiency.

NOTE—

① Any "Butcher Boy" cold storage door can be hung either right hand or left hand at any time without change in construction as all "Butcher Boy" doors have full width hinge blocks.

② All "Butcher Boy" doors maintain a 100% tight seal, and insure ease in opening and closing operations at all times because of exacting standards of construction.

"Butcher Boy" NEW-TYPE HARDWARE can be installed on *any* cold storage door

• Super-Seal FASTENERS

"Super Seal" Fasteners maintain a 100% tight seal between the door gaskets and frame, thereby preventing WARPING and DOOR ICING.

CONSTANT AUTOMATIC PRESSURE is brought against the door gaskets by two (2) Extra Heavy Duty fasteners

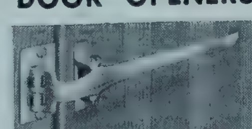
DOUBLE CONTACT locking feature of "Super Seal" replaces the old inefficient single contact fasteners, distributes even pressure upon the entire surface of the door and its gaskets.

EASY TO INSTALL on any door . . . adjustments are simple and positive with lock nut settings

DURABLE, HEAVY, MODERN . . . each "Super Seal" fastener weighs 10 lbs

• FINGER-TIP DOOR OPENERS

Minimize the efforts of opening heavy cold storage doors by application of the laws of "leverage".



Mere "finger-tip" pressure will open any size door.

Installed without drilling holes through the doors—eliminates the necessity of push rods which frequently stick, freeze, or bend.

Extra heavy, long, modernistic handles—designed for perfect operation on an 8 to 1 "leverage" ratio.

"Finger-Tip" openers "snap" back into closed position after each operation eliminating the ever constant threat of tearing clothing or catching on a protruding handle.

Write for Bulletins

VESTIBULE DOORS are used primarily to save refrigeration costs where long periods of opening prevail.

Since 1885 "Butcher Boy" PRODUCTS

BUTCHER BOY COLD STORAGE DOOR CO.
170-180 N. SANGAMON ST. ★ CHICAGO 7, ILL. U. S. A.

COMPOUNDS, WATERPROOFING (Continued)

Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.
A. C. Horn Co., Inc., 43-36-10th St., Long Island City, N.Y.
Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N.J.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Lexington Supply Co., 4815 Lexington Ave., Cleveland 3, O.
Master Mechanics Co., Freeman Rd., Cleveland 13, O.
Midland Paint & Varnish Co., 3801 E. 91st St., Cleveland 5, O.
North American Fibre Products Co., Standard Bldg., Cleveland 13, O.
Pecora Paint Co., Inc., 3rd & Lawrence Sts., Phila. 40, Pa.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10, Mo.
H. H. Robertson Co., 2400 Farmers' Bank Bldg., Pittsburgh 22, Pa.
Smooth-On Mfg. Co., 572 Communipaw Ave., Jersey City 4, N.J.
L. Sonneborn Sons, Inc., 88 Lexington Ave., N.Y.C. 16
Stancal Asphalt & Bitumuls Co., 200 Bush St., San Francisco 4, Cal.
Steelcote Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo.
Tamms Industries, Inc., 228 N. La Salle St., Chicago 1, Ill.
Tempo Chemical Co., Inc., 4-88-47th Ave., Long Island City 1, N.Y.
Tuco Products Corp., 30 Church St., N.Y.C. 7
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.

COMPOUNDS, WATER TREATING (See **WATER TREATING**)

COMPRESSORS, AIR, GAS, etc.

Binks Mfg. Co., 3114 Carroll Ave., Chicago 16, Ill.
Brunner Mfg. Co., Utica 1, N.Y. *(p. 65)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlein Ave., St. Louis 20, Mo. *(p. 49)*
Cooper-Bessemer Corp., Mt. Vernon, O.
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
DeVilbiss Co., 300 Phillips Ave., Toledo 1, O.
Electric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
Fuller Co., Box 420, Catasauqua, Pa. *(p. 161)*
Hooven, Owens, Rentschler Div., General Machinery Corp., 545 N. 3rd St., Hamilton, O.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Joy Mfg. Co., Oliver Bldg., Pittsburgh, Pa.
Lynch Mfg. Corp., 3600 Summit St., Toledo 1, O.
Mills Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. *(p. 60)*
Nash Engrg. Co., 358 Wilson Rd., S. Norwalk, Ct.
Niles Tool Wks. Div., General Machinery Corp., 545 N. 3rd St., Hamilton, O.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14 Ill.
Pennsylvania Pump & Compressor Co., Easton, Pa.
Quincy Compressor Co., 217 Maine St., Quincy, Ill.
Roots-Connersville Blower Corp., P.O. Box 327, Conners ville, Ind.
Schnacke, Inc., 1016 E. Columbia St., Evansville 7, Ind
B. F. Sturtevant Div., Westinghouse Elec. Corp. 101 Readville St., Boston 36, Mass. *(p. 16*
Union Steam Pump Co., Battle Creek, Mich.
United Engine Co., W. Holmes Rd., Lansing 12, Mich.
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 116*
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill

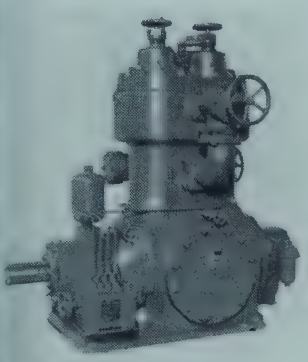
COMPRESSORS, AMMONIA (See also **CONDENSING UNITS, AMMONIA**)

Baker Refrigeration Corp., S. Windham, Me. *(p. 48*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45*
Clark Bros. Co., Inc., Olean, N.Y.
Cooper-Bessemer Corp., Mt. Vernon, O.
Creamery Package Mfg. Co., 1243 W. Washingto Blvd., Chicago 7, Ill. *(p. 50*
Cyclops Iron Wks., 837 Folsom St., San Francisco 7, Ca
Dersch, Gesswein & Neuert, Inc., 4845 W. Gran Ave., Chicago 39, Ill. *(p. 19*
Frick Co., Waynesboro, Pa. *(p. 44*
Fuller Co., Box 420, Catasauqua, Pa. *(p. 161*
General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. *(p. 58*
Howe Ice Machine Co., 2825 Montrose Ave., Chicag 18, Ill. *(p. 42*
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Reco Products Div., Refrigeration Engrg. Corp., 202 Naudain St., Phila. 46, Pa.
Reliance Refrigerating Machine Co., 3401 N. Kedzi Ave., Chicago 18, Ill.
Reynolds Mfg. Co., Inc., Springfield, Mo.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Ca
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43*
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 116*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Il
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill
York Corp., York, Pa. *(p. 119*

COMPRESSORS, BOOSTER

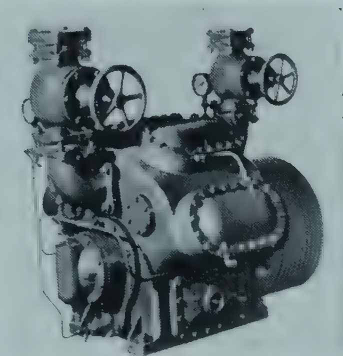
Baker Refrigeration Corp., S. Windham, Me. *(p. 48*
Creamery Package Mfg. Co., 1243 W. Washingto Blvd., Chicago 7, Ill. *(p. 50*
Frick Co., Waynesboro, Pa. *(p. 44*
Howe Ice Machine Co., 2825 Montrose Ave., Chicag 18, Ill. *(p. 42*
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Reco Products Div., Refrigeration Engrg. Corp., 202 Naudain St., Phila. 46, Pa.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119*

Whatever Your Needs in Refrigeration—
You Can DEPEND on VILTER



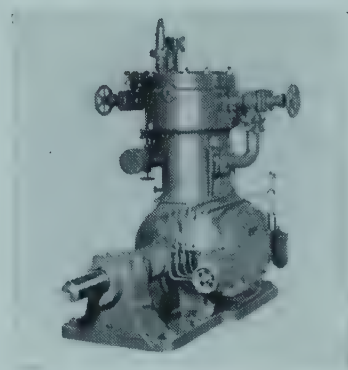
VERTICAL COMPRESSORS

Ammonia units in sizes from 4 to .00 tons each. Modern design reon units with rotary shaft seals, rom ¼ h.p. to 50 h.p. Horizontal compressors from 50 tons upward, or electric or steam drive.



VMC COMPRESSORS

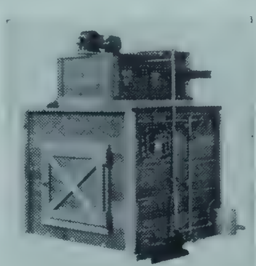
Latest type multi-cylinder compressors, with 4, 6, or 8 cylinders, for freon or ammonia. Completely balanced, VMC's require no expensive foundation. All Vilter units are built *entirely* by Vilter.



BOOSTER COMPRESSORS

Champions of economy for low temperature refrigeration. Sizes range from 60 to 600 cubic feet per minute in vertical units. Larger capacities in two-stage horizontals. Completely Vilter-built as usual.

THE VILTER PAKICER



Make your own Crystalform PakIce and save money. Vertical PakIce units make from 1 to 6 tons of ice in 24 hours. Horizontal units, 10 to 30 tons.

SHELL AND TUBE CONDENSERS

Any size from one ton upward, in horizontal or vertical design, for ammonia or freon. Vilter condensers stand up longer because they're built far better.

SEE YOUR Vilter representative for more information about these Vilter products, or Vilter Air Conditioners, Quick Freezing Systems, Pipe Coils and Refrigeration Piping, or Valves and Fittings. You're ahead with refrigeration by Vilter.

WRITE FOR CATALOGS

. . . on any of these Vilter products. Longer life and less trouble save you money with Vilter.

Vilter

REFRIGERATION and AIR CONDITIONING

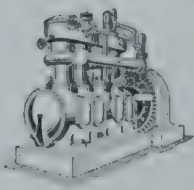
THE VILTER MANUFACTURING COMPANY
MILWAUKEE 7, WISCONSIN

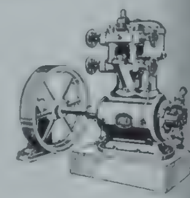
Ammonia and Freon Compressors • Pak Icers • Evaporative and Shell and Tube Condensers • Pipe Coils • Valves and Fittings

Frick Company

Waynesboro **Pennsylvania**

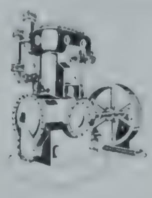
Branch Offices and Distributors in Principal Cities

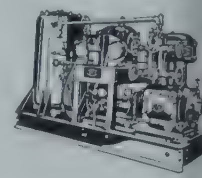

Large 4-Cylinder Compressors, for Ammo. or Freon-12


2-Cylinder Ammonia Compressors

AMMONIA REFRIGERATION

Capacities up to 1000 tons in one unit. Compressors feature water jacket over cylinder heads, outboard bearing beyond wheel, force-feed oiling, and patented Flexo-Seals. Capacity controls, dual-pressure cylinders, etc., supplied on order. Booster compressors save power for low temperature Frick-freezing systems. See Bulletins 104, 112, 516 and 651.

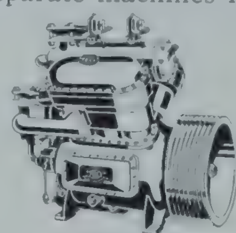

2-Cyl. Booster Compressor

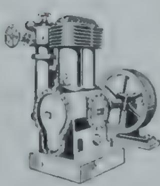

Combined Ammonia Unit

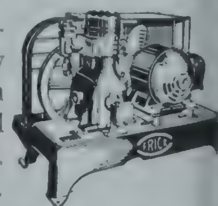
LOW-PRESSURE REFRIGERATION

Units from ¼ through 15 hp. Air and water cooled, for Freon-12. Separate machines in sizes 5¾″ x 4″ through 17¾″ x 12″, four cylinder.

The NEW "ECLIPSE" machines, 4⅜″ x 4¼″ give big capacity in small space, have many exclusive features. Flexo-Seals, force-feed oiling, dynamic balancing, capacity controls with water cooled valve plates. Bul. 97 & 100.

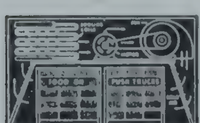

Frick NEW "ECLIPSE" Compressors have 2, 3, 4, 6 or 9 Cylinders


2-Cyl. Freon-12 Compressors


Low Pressure Unit

AIR CONDITIONING SYSTEMS

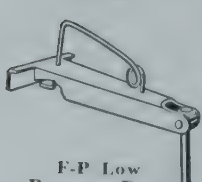
Complete systems, as well as unit conditioners, also refrigeration for use with equipment built by others. Ask for Bulletins 502, 503, 504, and 505.

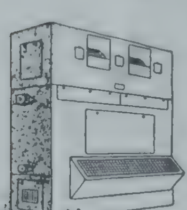

Section thru Frick-Freezing System

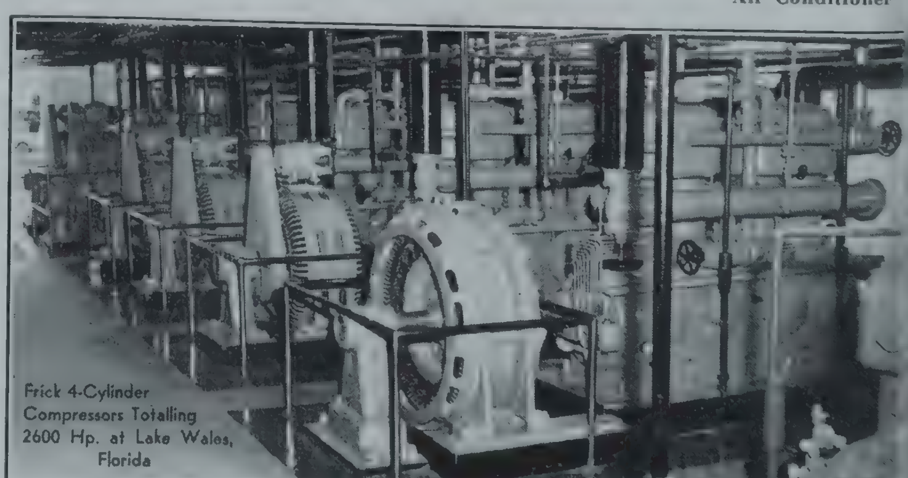

Frick Unit Air Conditioner

ICE-MAKING SYSTEMS

Loose can or group lift; brine race with Vertiflow unit or brine cooler systems; manual or automatic control. Bulletins 50, 51, 127 and 141.


F-P Low Pressure Drop Tube & Bracket for Ice Plants


Evaporative Condenser


Frick 4-Cylinder Compressors Totalling 2600 Hp. at Lake Wales, Florida

Carrier Corporation · Syracuse 1, New York

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385 Madison Ave.
New York 17, N.Y.

Carrier

INTERNATIONAL DIVISION
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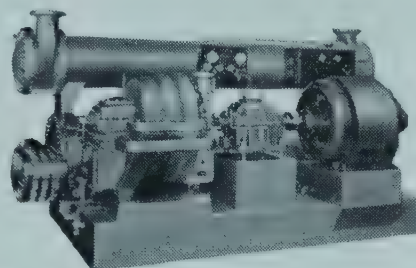
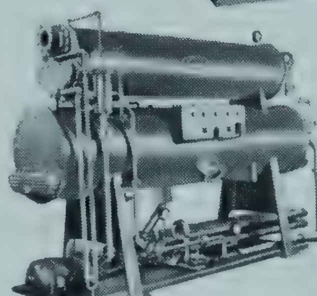
New York 17, N.Y.

Offices and Dealers in all principal cities—refer to your telephone directory



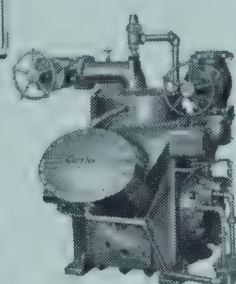
entrifugal Refrigerating Machines

or large scale air conditioning, low temperature rocess refrigeration, direct or indirect cooling of ater, brines, hydrocarbons and other liquids, nd for liquefaction of vapors and gases. Any andard motor or turbine drive may be applied. vailable in capacities from 100 to 1200 tons ooling.



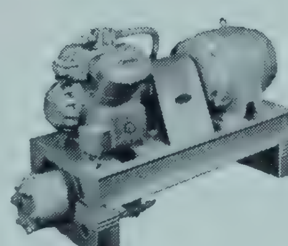
bsorption Refrigerating Machines

'or producing chilled water at 36F or higher in fully automatic operation between 15 and 100 ercent capacity. Uses high or low pressure steam or operation with salt and water solution as the bsorbent. Available in capacities of 115, 150 and 00 tons.



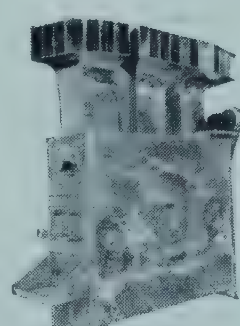
eciprocating Refrigerating Machines

For comfort and industrial air conditioning of noderate size and for process cooling. Direct or elt drive, water or evaporative cooled types rom 5 to 100 horsepower.



Reciprocating Compressors

For refrigeration needs of air conditioning and process cooling. Adaptable to all types of drives and available for use with "Freon" and ammonia refrigerants from 75 to 200 horsepower.



Blast Freezers and Cold Diffusers

For food freezing and storage, meat packing operations and other industries requiring medium and low temperatures. Units are available in suspension or floor models, dry coil and spray type in capacities up to 36 tons.

Evaporative Condensers

For use with refrigerating compressors in place of water cooled condensers or cooling towers. Suitable for indoor or outdoor location. Simplify water supply and disposal problems. Available in four standard sizes ranging in capacities from 5 to 75 tons.

Write for descriptive literature on any of the above equipment

COMPRESSORS, CARBON DIOXIDE

Frick Co., Waynesboro, Pa. (p. 44)
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
Wittenmeier Machinery Co., 850 Spaulding N. Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)

COMPRESSORS, CENTRIFUGAL (See also CONDENSING UNITS, CENTRIFUGAL)

Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45)
Clark Bros. Co., Inc., Olean, N.Y.
Trane Co., La Crosse, Wis. (p. 12)
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)

COMPRESSORS, FREON, METHYL, etc. (See also CONDENSING UNITS)

Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton 1, O.
Baker Refrigeration Corp., S. Windham, Me. (p. 48)
Brunner Mfg. Co., Utica 1, N.Y. (p. 65)
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45)
Copeland Refrigeration Corp., Sidney, O. (p. 63)
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. (p. 50)
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlen Ave., St. Louis, 20, Mo. (p. 49)
Diceler Div., General Machine & Mfg. Co., Blair St. & Spring Ave., Berwick, Pa.
Frick Co., Waynesboro, Pa. (p. 44)
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. (p. 6)
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. (p. 66)
General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. (p. 58)
Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. (p. 42)
Kelvinator Div., Nash-Kelvinator Corp., 1425[illegible] Plymouth Rd., Detroit, Mich. (p. 59)
Lehigh Mfg. Co., Div. of Lehigh Foundries, Inc., 14[illegible] Fountain Ave., Lancaster, Pa. (p. 46)
Lynch Mfg. Corp., 3600 Summit St., Toledo 1, O.
Mills Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. (p. 60)
Reliance Refrigerating Machine Co., 3401 N. Kedzie Ave., Chicago 18, Ill.
Schnacke, Inc., 1016 E. Columbia St., Evansville 7, Ind.
Servel, Inc., Evansville 20, Ind.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 10[illegible] Readville St., Boston 36, Mass. (p. 16)
Tecumseh Products Co., Tecumseh, Mich. (p. 61)
Typhoon Air Conditioning Co., Inc., Div. of Ice Air Conditioning Co., Inc., 794 Union St., Brooklyn 15, N.Y.
Universal Cooler Div., Newport Steel Corp., 29[illegible] Joseph St., Marion, O. (p. 47)
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. (p. 119)

COMPRESSOR PARTS, DRAWN OR STAMPED (See also STAMPINGS; also SHAPES, DRAWN, etc.)

Acklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. (p. 185)
Bingham-Herbrand Corp., 1062 Post St., Toledo 6, O.
Chicago Seal Co., 232 S. Hoyne Ave., Chicago 20, Ill.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. (p. 29)
Metal Specialty Co., Este Ave., & B&O R.R., Cin'ti., O

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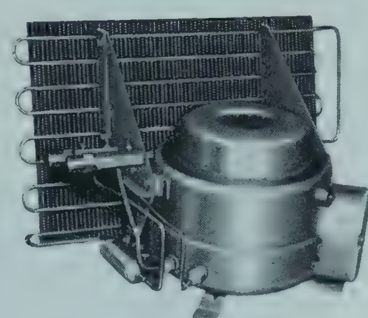
THE MOST COMPLETE LINE OF REFRIGERATION CONDENSING UNITS IN THE INDUSTRY

● Universal Cooler offers you the most complete ne of refrigeration condensing units in the industry -unmatched ability to solve ANY refrigeration roblem you might encounter. This is only one of nany advantages you get when you bring your efrigeration problems to Universal Cooler.

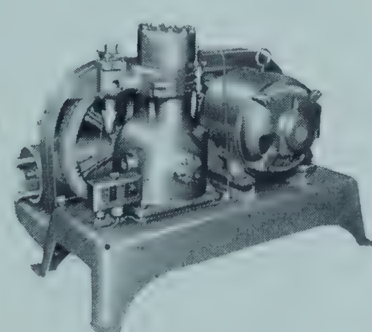
'rompt handling of shipments is another feature of Jniversal Cooler service. Standard units and ompressors are carried in stock for quick shipment. Replacement parts are available in more than 200 cities across the country through manufacturers and franchised wholesalers. This availability of parts greatly strengthens customer acceptance of Universal Cooler units, and simplifies servicing and naintenance problems.

NOTE TO MANUFACTURERS — Universal Cooler representatives are strategically located throughout the United States, available to assist you with your special problems. Write for names of representatives nearest you.

Below—
HERMETIC UNITS—split phase and capacitor types, ⅛ H.P. to 1 H.P.



Below—
REMOTE TYPE
¼ H.P. to 15 H.P.

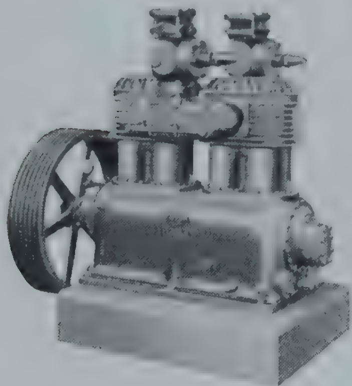


NOT ILLUSTRATED—
SELF-CONTAINED—
1/6 H. P. to 3/4 H. P.

UNIVERSAL COOLER
MARION, OHIO

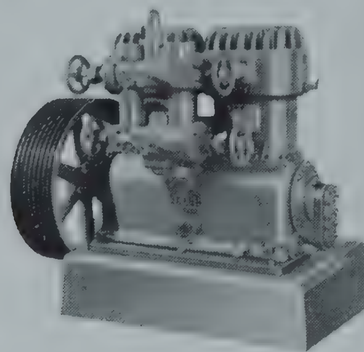
SOLD THROUGH MANUFACTURERS AND FRANCHISED WHOLESALERS

Freon BAKER *Ammonia*



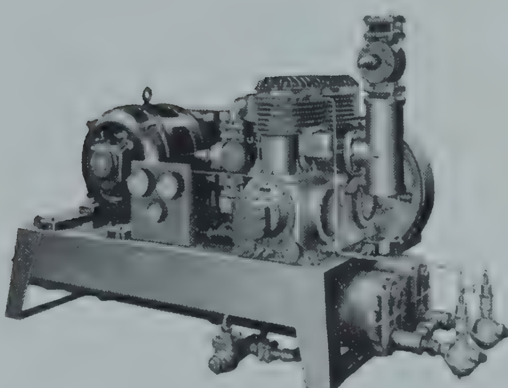
Four-cylinder type (as shown) is available in sizes 3 to 60 H.P.; other types down to ½ H.P. Also compressor-motor units with built-in electrical controls.

FREON COMPRESSORS
½ to 60 H.P.



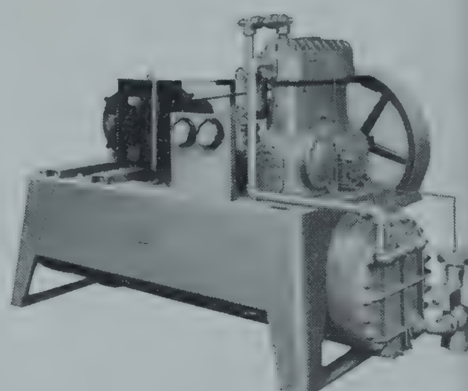
Vertical enclosed, single-acting 2 and 4 cylinder types. Double suction and capacity reduction in larger sizes. Also compressor-motor units, 2 to 20 H.P. with automatic controls.

AMMONIA COMPRESSORS
2 to 125 H.P.



Two and four-cylinder types mounted on rigid frame with V-belt drive motor, guard, shell and tube condenser, and all controls.

FREON CONDENSING UNITS
½ to 60 H.P.



Water-cooled, compact design. Shell and tube type condenser with pressure-operated water control valve. Mounted on rigid frame with V-belt drive motor, guard and all controls.

AMMONIA CONDENSING UNITS
2 to 15 H.P.

An Outstanding Line of Air Conditioning & Refrigeratio Equipment for all Applications

Enlarged manufacturing facilities assure Baker quality plus prompt delivery. The line includes Shell and Tube Condensers and Liquid Coolers (1 to 250 tons capacity); Evaporative Condensers; Valves and Fittings; Heat Transfer Products. Baker "packaged" un include BAKERAIRE (3, 5, 7½ and 10 ton) a BAKER CENTRAL-AIR (5 to 40 ton). For catalo and data sheets address

BAKER REFRIGERATION CORPORATIO

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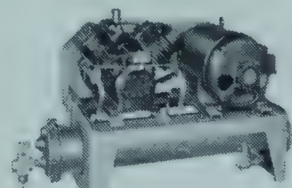
Branch Offices: New York, Washington, St. Louis, Omaha, Neb. Seattle, Portland, Ore., San Francisco, Los Angeles

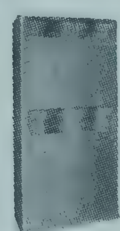


WATER-COOLED CONDENSING UNITS—Shell and Tube Type

You can increase your profits because you can handle any

AIR CONDITIONING • REFRIGERATION • OR AIR MOVING JOB

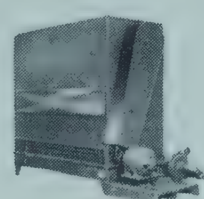
with Curtis equipment



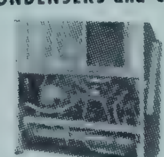
Nationally Advertised in Saturday Evening Post, Times and Newsweek

PACKAGED TYPE AIR CONDITIONERS—2½-8 Ton

The new Curtis line reflects the many advantages gained from almost a century of accumulated experience in engineering, designing and manufacturing. You can install Curtis equipment with the knowledge beforehand that it will operate dependably with the highest degree of efficiency and quietness. Your customer will be happy, your reputation enhanced, your profits greater. Write for complete detailed information about a Curtis franchise.



EVAPORATIVE CONDENSERS and COOLING TOWERS



CENTRAL TYPE AIR CONDITIONERS—10 and 15 Ton

95 YEARS of SUCCESSFUL MANUFACTURING

CEILING and FLOOR TYPE AIR HANDLING UNITS

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of CURTIS MANUFACTURING COMPANY
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ern Industries, Inc., 296 Elm St., New Haven 6, Ct.

NDENSER WATER DISTRIBUTORS

k Co., Waynesboro, Pa. (p. 44)
Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
A. Martocello & Co., 229 N. 14th St., Phila. 7, Pa. (p. 147)
o Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
er Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
rthington Pump & Machinery Corp., Harrison, N.J. (p. 116)

NDENSER WATER REGULATING VALVES

inco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. (p. 149)
tomatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. (p. 96)
Valve Co., 4662 N. Lincoln Ave., Chicago 25, Ill.
ker Refrigeration Corp., Inc., S. Windham, Me. (p. 48)
W. Cash Co., 540 N. 18th St., Decatur, Ill.
ctrimatic Div., Jas. P. Marsh Corp., 3501 Howard St., Skokie, Ill.
son-Neilan Regulator Co., 1190 Adams St., Boston 24, Mass.
eller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
nn Elec. Switch Co., Goshen, Ind. (p. 71)
rus Shank Co., 625 W. Jackson Blvd., Chicago 6, Ill.
rk Corp., York, Pa. (p. 119)

NDENSERS, AIR COOLED

ldison Mfg. Co., Inc., Addison, Mich.
nerican Coils Co., 25 Lexington St., Newark 5, N.J.
own Fintube Co., Elyria, O.
ush Mfg. Co., 179 South St., W. Hartford 10, Ct. (p. 200)
arrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45)
rayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
vans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
edders-Quigan Corp., 57 Tonawanda St., Buffalo 7, N.Y. (p. 53)
& O Mfg. Co., 138 Winchester Ave., New Haven 8, Ct.
eneral Refrigeration Div., Yates-American Machine Co., Beloit, Wis. (p. 58)
oudaille-Hershey Corp., 1900 Foss Park Ave., N. Chicago, Ill. (p. 51)
ussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. (p. 81)
elvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. (p. 59)
Kirsch Co., Sturgis, Mich.
Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. (p. 202)
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
Long Mfg. Div., Borg-Warner Corp., 12501 Dequindre St., Detroit 12, Mich.
McCord Corp., Riopelle & E. Grand Blvd., Detroit 11, Mich. (p. 37)
McQuay Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. (p. 203)
Mills Industries, Inc., 4100 Fullerton Ave., Chicago 39, Ill. (p. 60)
Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. (p. 211)
Rome-Turney Radiator Co., Rome, N.Y. (p. 39)
Rudy Mfg. Co., Dowagiac, Mich.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., Boston 36, Mass. (p. 16)
Trane Co., La Crosse, Wis. (p. 12)
Universal Cooler Div., Newport Steel Corp., 299 Joseph St., Marion, O. (p. 47)
Warren Co., Inc., P.O. Box 1436, Atlanta 1, Ga.
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)
Young Radiator Co., Racine, Wis. (p. 9)

CONDENSERS, ATMOSPHERIC

Crane Co., 836 Michigan Ave., Chicago 5, Ill. (p. 105)
Frick Co., Waynesboro, Pa. (p. 44)
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Roessing Mfg. Co., Sharpsburg Sta., Pittsburgh, Pa.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)

CONDENSERS, CARBON DIOXIDE

Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. (p. 56)
Frick Co., Waynesboro, Pa. (p. 44)
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)

RICHARD M. ARMSTRONG CO.

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WEST CHESTER, PA.

HEAT TRANSFER DESIGNERS AND BUILDERS

LIQUID—SUCTION HEAT EXCHANGERS
5 to 200 Tons Capacity

New Design gives *practically no pressure loss*
High Superheat (65F outlet temp.)
Low Cost per ton of capacity

These exchangers are most useful on low temperature jobs and water cooling jol Avoid sweatback by boiling liquor out of suction vapor, thereby also helping to redu oil pumping by compressor. Sweat or pipe outlets available.

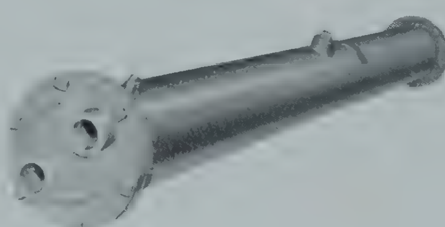
FREON CONDENSERS—1 TO 300 TONS

LAND

Copper Finned Tubes—rolled into steel tube sheet

Shell—steel

Heads—cast iron



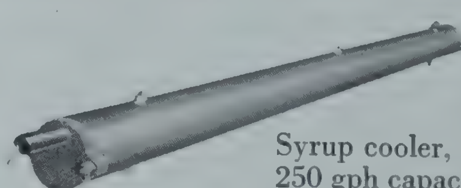
MARINE

Tubes—Cupronicke finned
Tube Sheets—Cupr nickel or mon clad steel
Shell—steel
Heads—cast iron

SHELL AND TUBE
A.S.M.E. Stamped When Required

LIQUID COOLERS—SHELL AND TUBE

Dry Expansion Water Chillers
Flooded Water Chillers
Vegetable Oil Chillers
Stainless Steel Coolers
Brine Coolers



Syrup cooler,
250 gph capacity

ALL DESIGNS BACKED BY MANY YEARS OF HEAT TRANSFER EXPERIENCE

MISCELLANEOUS SHELL AND TUBE HEAT EXCHANGERS
LIQUID RECEIVERS **OIL SEPARATORS TO 150 H.**

FEDDERS-QUIGAN CORPORATION

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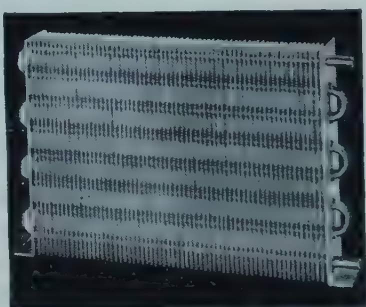
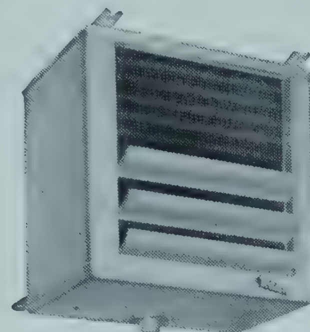
A Great Name Since 1896

FEDDERS CONDENSERS

FEDDERS UNIT COOLERS



hoto shows Fedders Continuous Tube Condenser



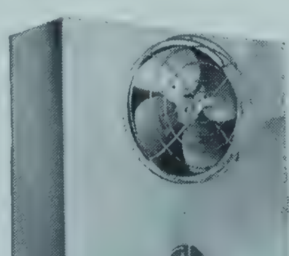
Horizontal Type

Fedders patented split fin construction lows use of continuous tubes without ints. Possibility of leaks is eliminated. ll fins have full flange contact entirely ound 360° circumference of tubes. Fins e permanently bonded to tubes by copper razing. Proper fin-tube ratio provides aximum heat transfer.

Internal cleanliness guaranteed to 4 mg er 10 ft. length of tube. Fins are bonded to ibes by copper brazing for permanent etal-to-metal contact. Fins have full ange contact entirely around circum- erence of tubes. Available in single and ultiple rows providing balanced capacity or standard air cooled condensing units. End brackets are brazed to tubes for trength and rigidity. Feet have slotted oles for convenient installation. Thou- ands used as standard equipment and for eplacements. All condensers over ½ HP re manifolded. Write for specifications.

Fedders Unit Coolers are made in suspended and panel types. Sturdy, rust-proof cabinets, high efficiency cooling element, quiet fans and thorough dehydration are features responsible for performance. Heat exchanger is standard equipment on all but smaller sizes. Conservative, accurate ratings safeguard customer satisfaction.

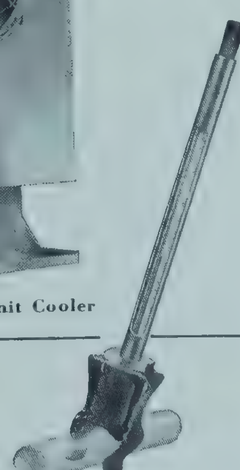
Complete line of well-graduated capacities to match all standard condensing units. Write for catalog.



Fedders Panel Type Unit Cooler

SUPERHEAT THERMOMETER

Simplifies accurate setting of controls and balancing of refrigeration and air conditioning systems. They are a necessity for every installation and service engineer. Write for data.



CONDENSERS, COMBINATION AIR & WATER COOLED

Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45)
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Harry Cooling Towers, Inc., West St., Doylestown, Pa. (p. 74)
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 (p. 122)
Long Mfg. Div., Borg-Warner Corp., 12501 Dequindre St., Detroit 12, Mich.
Mills Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. (p. 60)
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
Standard Refrigeration Co., 232 S. Hoyne Ave., Chicago 20, Ill.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., Boston 36, Mass. (p. 16)
York Corp., York, Pa. (p. 119)

CONDENSERS, DOUBLE PIPE

California Steel Products Co., Barrett & "A" Sts., Richmond, Cal.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45)
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. (p. 50)
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. (p. 56)
Frick Co., Waynesboro, Pa. (p. 44)
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
L. O. Koven & Bro., Inc., Jersey City 7, N.J.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. (p. 55)
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Roessing Mfg. Co., Sharpsburg Sta., Pittsburgh, Pa.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)

CONDENSERS, DOUBLE TUBE

Baker Refrigeration Corp., S. Windham, Me. (p. 48)
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45)
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. (p. 56)
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
Frick Co., Waynesboro, Pa. (p. 44)
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. (p. 58)
Halstead & Mitchell, Bessemer Bldg., Pittsburgh 22, Pa. (Cleanable) (p. 57)
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 (p. 122)
Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. (p. 81)
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. (p. 59)
McCord Corp., Riopelle & E. Grand Blvd., Detroit 11, Mich. (p. 37)
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Reese & Long Refrigeration Products, Inc., 408 E. 25th St., N.Y.C. 10
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. (p. 211)
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Rome-Turney Radiator Co., Rome, N.Y. (p. 39)
Standard Refrigeration Co., 232 S. Hoyne Ave., Chicago 20, Ill.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)

CONDENSERS, ELECTRIC (See CAPACITORS)

CONDENSERS, EVAPORATIVE (See EVAPORATIVE CONDENSERS)

CONDENSERS, SHELL & COIL

Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. (p. 21
Richard M. Armstrong Co., Box 188, W. Chester, Pa (p.
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Ill
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 4
Cleveland Coppersmithing Wks., 5500 Stone Ave., Cleveland 2, O.
Croll Reynolds Engrg. Co., Inc., 17 John St., N.Y.C.
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlein Ave., St. Louis 20, Mo. (p. 4
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 3 N.Y. (p. 5
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 3 Cal.
John J. Dupps Co., Germantown, O.
Frick Co., Waynesboro, Pa. (p. 4
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. (p. 6
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 (p. 12
Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. (p.
Kelvinator Div., Nash-Kelvinator Corp., 142 Plymouth Rd., Detroit, Mich. (p. 5
L. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City N.J.
Kramer Trenton Co., Olden & Bruening Ave Trenton 5, N.J. (p. 2
Long Mfg. Div., Borg-Warner Corp., 12501 Dequind St., Detroit 12, Mich.
McCord Corp., Riopelle & E. Grand Blvd., Detr 11, Mich. (p.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. (p.
Reco Products Div., Refrigeration Engrg. Corp., 20 Naudain St., Phila. 46, Pa.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. (p. 2
Reliance Refrigerating Machine Co., 3401 N. Kedzie Av Chicago 18, Ill.
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill
Edw. Renneburg & Sons Co., 2639 Boston St., Baltim 24, Md.
Roessing Mfg. Co., Sharpsburg Sta., Pittsburgh, Pa.
Rome-Turney Radiator Co., Rome, N.Y. (p.
Standard Refrigeration Co., 232 S. Hoyne Ave., Chic 20, Ill.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, C
B. F. Sturtevant Div., Westinghouse Elec. Co., Readville St., Boston 36, Mass. (p.
Trane Co., La Crosse, Wis. (p.
Typhoon Air Conditioning Co., Inc., Div. of Ice Conditioning Co., Inc., 794 Union St., Brooklyn N.Y.
Vilter Mfg. Co., 2223 S. 1st St., Milwaukee 7, Wis (p.
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Worthington Pump & Machinery Corp., Harris N.J. (p. 1
XL Refrigerating Co., 1834 W. 59th St., Chicago 36,
York Corp., York, Pa. (p. 1

CONDENSERS, SHELL & TUBE

Acme Industries, Inc., Mechanic & Ganson St Jackson, Mich. (p. 2
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

(Continu

CONDENSERS, SHELL & TUBE (Continued)

Andale Co., 1750 Cherry St., Phila. 3, Pa.
Richard M. Armstrong Co., Box 188, W. Chester, Pa. (p. 5
Baker Refrigeration Corp., Inc., S. Windham, Me. (p. 4
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Ill.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 45
Chattanooga Boiler & Tank Co., P.O. Box 110, Chattanooga, Tenn.
Cleveland Coppersmithing Wks., 5500 Stone Ave., Cleveland 2, O.
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. (p. 60
Croll-Reynolds Engrg. Co., 17 John St., N.Y.C.
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlein Ave., St. Louis 20, Mo. (p. 4
Davis Engrg. Corp., 104 E. Grand St., Elizabeth 4, N.J.
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. (p. 19
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. (p. 5
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 3 Cal.
John J. Dupps Co., Germantown, O.
Foster Wheeler Corp., 165 Broadway, N.Y.C.
Frick Co., Waynesboro, Pa. (p. 4
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.H. (p. 6
Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. (p. 4
Kramer-Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. (p. 20
Lehigh Fan & Blower Co., Div. of Heilman Boiler Wks., Inc., 128 Linden St., Allentown, Pa.
Lummus Co., 420 Lexington Ave., N.Y.C.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. (p. 5
Quaker City Iron Wks., Aramingo Ave. & E. Tioga St., Phila., Pa.
Reco Products Div., Refrigeration Engrg. Corp., 20 Naudain St., Phila. 46, Pa.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. (p. 20
Reliance Refrigerating Machine Co., 3401 N. Kedzie Av Chicago 18, Ill.
Reynolds Mfg. Co., Inc., Springfield, Mo.
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Stewart Ice Machine Co., 1282 W. 1st St., Pomona, C
B. F. Sturtevant Div., Westinghouse Elec. Corp., 1 Readville St., Boston 36, Mass. (p. 1
Trane Co., La Crosse, Wis. (p. 1
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7 Wis. (p. 4
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison N.J. (p. 11
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, I
York Corp., York, Pa. (p. 11

CONDENSING UNITS, AIR COOLED, FREON METHYL

Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton 1,
Baker Refrigeration Corp., S. Windham, Me. (p. 4
Blissfield Mfg. Co., 626 Depot St., Blissfield, Mich.
Brunner Mfg. Co., Utica 1, N.Y. (p. 6

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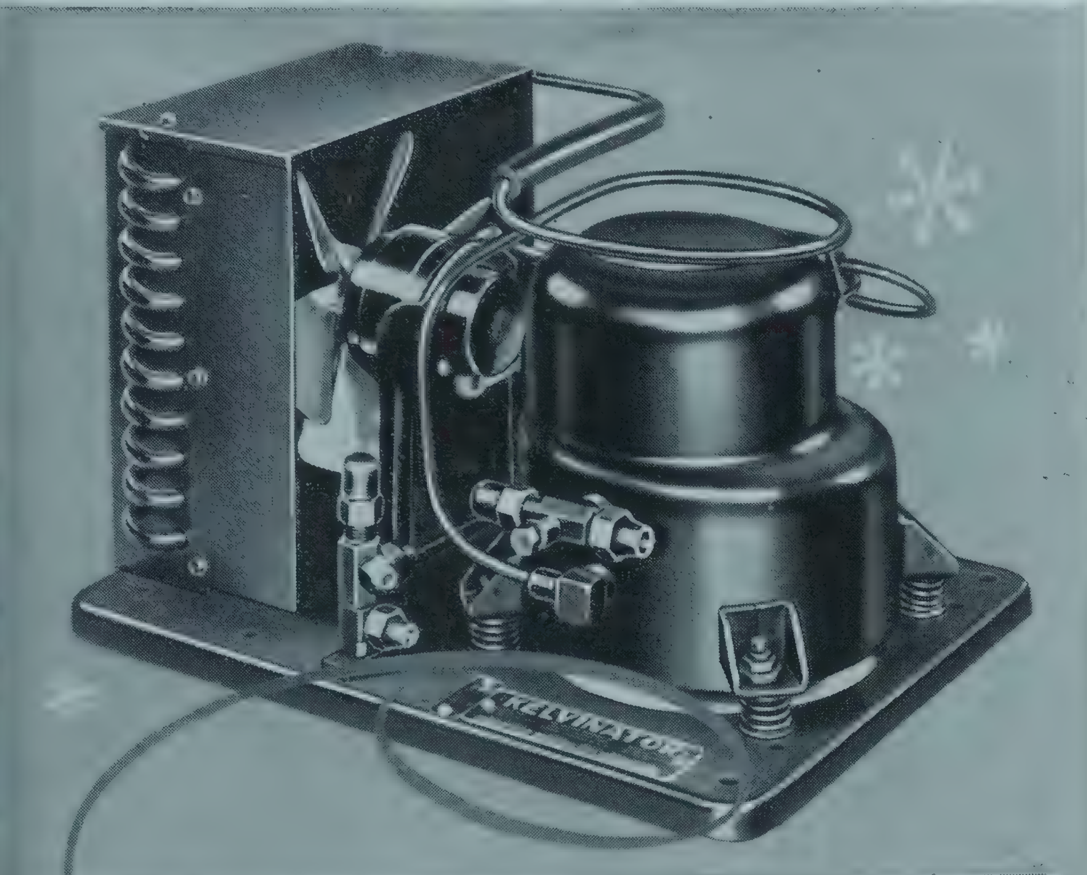
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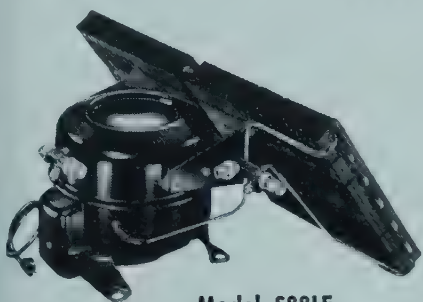

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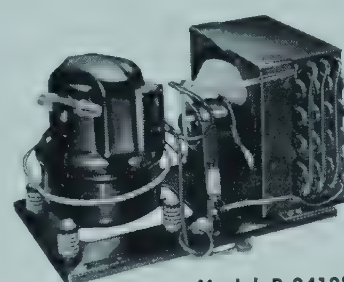
Model S88



Model B-2413H

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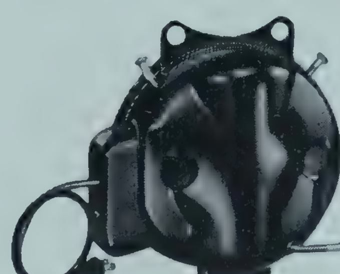

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CONDENSING UNITS, AIR COOLED (Continued)

Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (p. 4
Copeland Refrigeration Corp., Sidney, O. (p. 6
Creamery Package Mfg. Co., 1243 W. Washingto Blvd., Chidago 7, Ill. (p. 5
Crider Corp., 2216 Northland, Lakewood, O.
Curtis Refrigerating Machine Div., Curtis Mfg. Co 1949 Kienlein Ave., St. Louis 20, Mo. (p. 4
Dieeler Div., General Machine & Mfg. Co., Blair St. Spring Garden Ave., Berwick, Pa.
Fleetwood-Airflow, Inc., 421 N. Penna Ave., Wilkes-Barr Pa.
Frick Co., Waynesboro, Pa. (p. 4
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O (p.
General Elec. Co., Air Conditioning Dept., 5 Law rence St., Bloomfield, N.J. (p. 6
General Refrigeration Div., Yates-American Ma chine Co., Beloit, Wis. (p.
Howe Ice Machine Co., 2825 Montrose Ave., Chica 18, Ill. (p.
Hussmann Refrigeration, Inc., 2401 N. Leffingwe St. Louis 6, Mo. (p.
Kelvinator Div., Nash-Kelvinator Corp., 142 Plymouth Rd., Detroit, Mich. (p.
Lehigh Mfg. Co., Div. of Lehigh Foundries, Inc., Fountain Ave., Lancaster, Pa. (p.
Lynch Mfg. Corp., 3600 Summit St., Toledo 1, O.
Mills Industries, Inc., 4100 W. Fullerton Ave., Chi cago 39, Ill. (p.
Reliance Refrigerating Machine Co., 3401 N. Kedzie Av Chicago 18, Ill.
Servel, Inc., Evansville 20, Ind.
B. F. Sturtevant Div., Westinghouse Elec. Corp., Readville St., Boston 36, Mass. (p.
Tecumseh Products Co., Tecumseh, Mich. (p. 6
Trane Co., La Crosse, Wis. (p.
Universal Cooler Div., Newport Steel Corp., 2 Joseph St., Marion, O. (p.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis (p.
Worthington Pump & Machinery Corp., Harris N.J. (p. 1
XL Refrigerating Co., 1834 W. 59th St., Chicago 36,
York Corp., York, Pa. (p. 1

CONDENSING UNITS, AMMONIA

Baker Refrigeration Corp., S. Windham, Me. (p.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y (p.
Creamery Package Mfg. Co. 1243 W. Washingt Blvd., Chicago 7, Ill. (p.
Cyclops Iron Wks., 837 Folsom St., San Francisco 7, C
Dersch, Gesswein & Neuert, Inc., 4845 W. Gra Ave., Chicago 39, Ill. (p. 1
Frick Co., Waynesboro, Pa. (p.
General Refrigeration Div., Yates-American Ma chine Co., Beloit, Wis. (p.
Howe Ice Machine Co., 2825 Montrose Ave., Chic 18, Ill. (p.
Reco Products Div., Refrigeration Engrg. Corp., 2 Naudain St., Phila. 46, Pa.
Reliance Refrigerating Machine Co., 3401 N. Kedzie Av Chicago 18, Ill.
Reynolds Mfg. Co., Inc., Springfield, Mo.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, C
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis (p.
Henry Vogt Machine Co., 10th & Ormsby St., Louisv 10, Ky.
Worthington Pump & Machinery Corp., Harris N.J. (p. 1
XL Refrigerating Co., 1834 W. 59th St., Chicago 36,
York Corp., York, Pa. (p. 1

CONDENSING UNITS, CENTRIFUGAL

Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y (p.
Worthington Pump & Machinery Corp., Harris N.J. (p. 1
York Corp., York, Pa. (p. 1

CONDENSING UNITS, GASOLINE DRIVEN

Brunner Mfg. Co., Utica 1, N.Y. *(p. 65)*
Ready-Power Co., 11231 Freud Ave., Detroit 14, Mich.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Sterling Mfg. Co., 2523 Farnam St., Omaha, Neb.
Universal Cooler Div., Newport Steel Corp., 299 Joseph St., Marion, O. *(p. 47)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

CONDENSING UNITS, HERMETIC OR SEMI-HERMETIC, FREON & METHYL

Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton 1, O.
American Commercial Equip. Co., 4150 Holly Knoll, Los Angeles 27, Cal.
Copeland Refrigeration Corp., Sydney, O. *(p. 63)*
Crider Corp., 2216 Northland, Lakewood, O.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Lynch Corp., 3600 Summit St., Toledo 1, O.
Mills Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. *(p. 60)*
Servel, Inc., Evansville 20, Ind.
B. F. Sturtevant Div., Westinghouse Elec. Co., 101 Readville St., Boston 36, Mass. *(p. 16)*
Tecumseh Products Co., Tecumseh, Mich. *(p. 61)*
Universal Cooler Div., Newport Steel Corp., 299 Joseph St., Marion, O. *(p. 47)*
York Corp., York, Pa. *(p. 119)*

CONDENSING UNITS, HOUSEHOLD

Blissfield Mfg. Co., 626 Depot St., Blissfield, Mich.
Copeland Refrigeration Corp., Sidney, O. *(p. 63)*
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Mills Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. *(p. 60)*
Servel, Inc., Evansville, Ind.
Tecumseh Products Co., Tecumseh, Mich. *(p. 61)*
Universal Cooler Div., Newport Steel Corp., 299 Joseph St., Marion, O. *(p. 47)*

CONDENSING UNITS, PROPANE

Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Croll-Reynolds Engrg. Co., Inc., 17 John St., N.Y.C.
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlein Ave., St. Louis 20, Mo. *(p. 49)*
Propane Development Corp., 41 Murray St., N.Y.C. 7
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

CONDENSING UNITS, WATER COOLED, FREON & METHYL

Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton O.1,
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Brunner Mfg. Co., Utica 1, N.Y. *(p. 65)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Copeland Refrigeration Corp., Sidney, O. *(p. 63)*
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlen Ave., St. Louis 20, Mo. *(p. 49)*
Diceler Div., General Machine & Mfg. Co., Blair St., & Spring Garden Ave., Berwick, Pa.
Frick Co., Waynesboro, Pa. *(p. 44)*
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. *(p. 58)*
Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. *(p. 42)*
Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*

Kelvinator Div., Nash-Kelvinator Corp., 14 Plymouth Rd., Detroit, Mich. *(p.*
Lehigh Mfg. Co., Div. of Lehigh Foundries, Inc., Fountain Ave., Lancaster, Pa. *(p.*
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Reliance Refrigerating Machine Co., 3401 N. Ke Ave., Chicago 18, Ill.
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Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Ca
Trane Co., La Crosse, Wis. *(p.*
Typhoon Air Conditioning Co., Inc., Div. of Ice Air C ditioning Co., Inc., 794 Union St., Brooklyn 15,
Universal Cooler Div., Newport Steel Corp., Joseph St., Marion, O. *(p.*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p.*
Worthington Pump & Machinery Corp., Harris N.J. *(p.*
XL Refrigerating Co., 1834 W 59th St., Chicago 36,
York Corp., York, Pa. *(p.*

CONDUIT, ELECTRICAL

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P. R. Mallory & Co., Inc., 3029 E. Washington St dpls, Ind.
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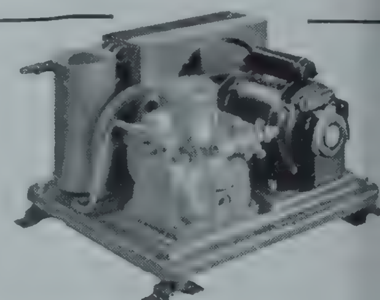
CONDENSING UNITS



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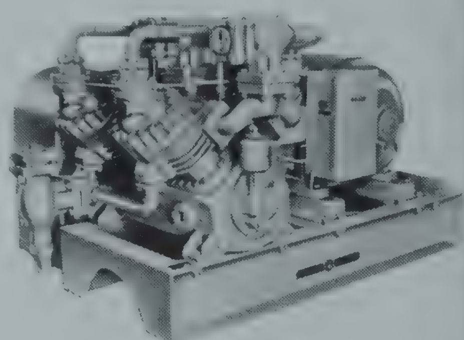

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vn Instrument Co., Div. Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
l Designs, Box 248, Forest Hills, N.Y.
eral Controls Co., 801 Allen Ave., Glendale, Cal. *(p. 67)*
nson Service Co., 507 E. Michigan St., Milwaukee 22, Wis.
coid Corp., 4201 Belmont Ave., Chicago 41, Ill.
neapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
ks-Cramer Co., Box 444, Fitchburg, Mass.
n Elec. Switch Co., Goshen, Ind. *(p. 71)*
rigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
psel Time Control, Inc., 600 N. Strong Ave., Spring Valley, Ill.
co Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
. Tagliabue Mfg. Co., 641 Frelinghuysen Ave., Newark 5, O.
lor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
ng Regulator Co., 5209 Euclid Ave., Cleveland 3, O.

NTROLS, DEFROSTING CYCLE

tomatic Elec. Mfg. Co., 10 State St., Mankato, Minn.
tomatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
gidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
ller Harris Instrument Co., 836 N. 4th St., Milwaukee 3, Wis.
nneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
ragon Elec. Co., 1600-12th St., Two Rivers, Wis.
nn Elec. Switch Co., Goshen, Ind. *(p. 71)*
nco Inc., 601 W. 5th Ave., Columbus 1, O. *(p. 69)*
rco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
ylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
rk Clock Co., Inc., 1 Grove St., Mt. Vernon, N.Y.
nsatt, Inc., Northampton, Mass.
hite-Rodgers Elec. Co., 1209 Cass Ave., St. Louis 6, Mo.

ONTROLS, HIGH PRESSURE OR HIGH PRESSURE CUTOUT
—Ammonia; B—Other refrigerants)

B) Allen-Bradley Co., Milwaukee 4, Wis.
,B) American Schaeffer & Budenberg Instrument Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
,B) Brown Instrument Co., Div. Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
,B) Cook Elec. Co., 2700 Southport Ave., Chicago 14, Ill.
B) Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
A,B) Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
B) **Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O.** *(p. 6)*
A,B) Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
ays Corp., Michigan City, Ind.
elvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
A,B) Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
B) **Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn.** *(p. 70)*
A,B) **Penn Elec. Switch Co., Goshen, Ind.** *(p. 71)*
B) **Ranco Inc., 601 W. 5th Ave., Columbus 1, O.** *(p. 69)*
A,B) Refrigerating Specialities Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
A,B) U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
B) White-Rodgers Elec. Co., 1209 Cass Ave., St. Louis 6, Mo.

CONTROLS, HUMIDITY

Bahnson Co., 1001 S. Marshall St., Winston-Salem 7, N.C.
Barber-Colman Co., Rockford, Ill.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div. Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Friez Instrument Div., Bendix Aviation Corp., Taylor Ave. at Loch Raven Blvd., Towson, Baltimore 4, Md.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Johnson Service Co., 507 E. Michigan St., Milwaukee 22, Wis.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Parks-Cramer Co., Box 444, Fitchburg, Mass.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Walton Laboratories, Inc., 1186 Grove St., Irvington 11, N.J.
White-Rodgers Elec. Co., 1209 Cass Ave., St. Louis 6, Mo.

CONTROLS, LIQUID LEVEL (See also FLOAT SWITCHES; also HIGHSIDE FLOATS; also LOWSIDE FLOATS, etc.)

Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
American Schaeffer & Budenberg Instrument Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div. Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.

(Continued)

CONTROLS, LIQUID LEVEL (Continued)

Builders-Providence, Inc., P.O. Box 1342 Providence 1, R.I.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Climax Engrg. Co., Controls Div., 15 N. Cincinnati, Tulsa, Okla.
Cochrane Corp., 17th St. below Allegheny Ave., Phila. 32, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Coral Designs, Box 248, Forest Hills, N.Y.
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
Ernst Water Column & Gage Co., 250 S. Livingston Ave., Livingston, N.J.
Fischer & Porter Co., Hatboro, Pa.
Frick Co., Waynesboro, Pa. *(p. 44)*
Hancock Valve Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Hays Corp., Michigan City, Ind.
Johnson Service Co., 507 E. Michigan St., Milwaukee 22, Wis.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Klipfel Valves, Inc., 1000 Weller Ave., Hamilton, O.
Liquidepth Indicators, Inc., 42-26-28th St., Long Island City 1, N.Y.
Liquidometer Corp., 41-03-36th St., Long Island City, 1 N.Y.
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
McAlear Mfg., Div. of Climax Industries, Inc., 15 N. Cincinnati, Tulsa, Okla.
McDonnell & Miller, Inc., 1316 Wrigley Bldg., Chicago 11, Ill.
Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Moore Products Co., H & Lycoming Sts., Phila. 24, Pa.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Schade Valve Mfg. Co., 2527 N. Bodine St., Phila. 33, Pa.
Soreng Mfg. Corp., 9555 Eden Ave., Schiller Park, Ill.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*

CONTROLS, MOTOR (See STARTERS)

CONTROLS, PROGRAM, SELECTIVE, SEQUENCE, etc. (See also TIME SWITCHES)

Arrow-Hart & Hegman Elec. Co., 103 Hawthorn St., Hartford 6, Ct.
Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Barber-Colman Co., Rockford, Ill.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div. Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Fischer & Porter Co., Hatboro, Pa.
Leeds & Northrup Co., 4970 Stenton Ave., Phila. 44, Pa.
Miller Harris Instrument Co., 836 N. 4th St., Milwaukee 3, Wis.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Paragon Elec. Co., 1600-12th St., Two Rivers, Wis.
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Tork Clock Co., Inc., 1 Grove St., Mt. Vernon, N.Y.
Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.

CONTROLS, SUCTION PRESSURE ACTUATED

(A—Ammonia; B—Other refrigerants)
(a—Close on rise; b—With H.P. cutout; c—Revers acting; d—With overload protection; e—Multipl circuit)

(A:a,b,c) Allen Bradley Co., Milwaukee 4, Wis.
(A,B:a,b,c) American Schaeffer & Budenberg Instrumer Div., Manning, Maxwell & Moore, Inc., Bridgepor 2, Ct.
(B:a,b,c,d) Cutler-Hammer, Inc., 315 N. 12 St., Milwau kee 1, Wis.
(A:a;B:a,b,c) Detroit Lubricator Co., 5900 Trumbu Ave., Detroit 8, Mich.
(B:a,b,d) Frigidaire Div., Gen'l. Motors Corp., Day ton 1, O. *(p. 6*
Kelvinator Div., Nash-Kelvinator Corp., 1425 Plymouth Rd., Detroit, Mich. *(p. 59*
(A,B:a,b,c,e) Mercoid Corp., 4201 Belmont Ave., Chicag 41, Ill.
(B:a,b,c,d,e) Minneapolis-Honeywell Regulator Co 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 7*
(A,B:a,b,c,d,e) Penn Elec. Switch Co., Goshen, In *(p. 71*
(B:a,b,c,d) Ranco Inc., 601 W. 5th Ave., Columbus O. *(p. 6*
(A,B:a,d) Refrigerating Specialties Co., 728 S. Sacr mento Blvd., Chicago 12, Ill.
(A,B:a,b) U. S. Gauge, Div. of American Machine Metals, Sellersville, Pa.
(B:a,b,c,e) White-Rodgers Elec. Co., 1209 Cass Ave., S Louis 6, Mo.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, I

CONTROLS, TEMPERATURE ACTUATED (See als THERMOSTATS)

Automatic Temperature Control Co., Inc., 5212 Pulas Ave., Phila. 44, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Barber-Colman Co., Rockford, Ill.
Barnes & Jones, Inc., 128 Brookside Ave., Jamaica Pla 30, Mass.
Brown Instrument Co., Div. Minneapolis-Honeywe Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wi
Defender Instrument & Regulator Co., 815 Clark Ave St. Louis 2, Mo.
Detroit Lubricator Co., 5900 Trumbull Ave., Detroit Mich.
Chas. Engelhard, Inc., 850 Passaic Ave., E. Newark, N.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p.*
General Controls Co., 801 Allen Ave., Glendale Cal. *(p. 6*
Johnson Service Co., 507 E. Michigan St., Milwaukee 2 Wis.
Kelvinator Div., Nash-Kelvinator Corp., 142 Plymouth Rd., Detroit, Mich. *(p. 5*
Klipfel Valves, Inc., 1000 Weller Ave., Hamilton, O.
Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4t Ave., S., Minneapolis 8, Minn. *(p. 7*
Paragon Elec. Co., 1600-12th St., Two Rivers, Wis.
Partlow Corp., 2 Campion Rd., New Hartford, N.Y.
Penn Elec. Switch Co., Goshen, Ind. *(p. 7*
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Ranco Inc., 601 W. 5th Ave., Columbus 1, O. *(p. 6*
Sampsel Time Control, Inc., 600 N. Strong Ave., Sprin Valley, Ill.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 17*
Spencer Thermostat Co., Unit of Metals & Controls Cor 34 Forest St., Attleboro, Mass.
G. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Nev ark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.
H. A. Thrush & Co., 21 E. Riverside Dr., Peru, Ind.
Tork Clock Co., Inc., 1 Grove St., Mt. Vernon. N.Y.
White-Rodgers Elec. Co., 1209 Cass Ave., St. Louis 6, M

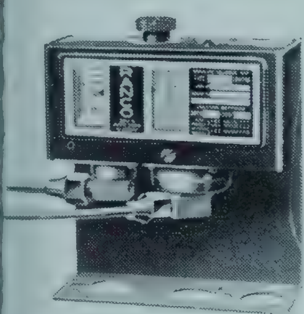
CONTROLLERS, DIESEL ENGINE

Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill
Minneapolis-Honeywell Regulator Co., 2933-4t Ave., S., Minneapolis 8, Minn. *(p. 7*

RANCO INC.
Columbus 1, Ohio, U.S.A.

Ranco Refrigeration Controls, designed and manufactured by refrigeration specialists, provide dependable, trouble-free service on the most exacting applications. The refrigeration industry uses more Ranco Controls than any other make. Check with Ranco Inc. first on your refrigeration control requirements.

Type "O" Refrigeration Controls
THE LEADING CONTROLS FOR FOOD PRESERVATION



)-1505

O-1401

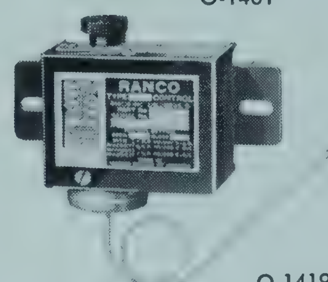
O-1505—DUAL PRESSURE COMMERCIAL CONTROL. High pressure cut-out independently adjustable. Single pole, snap acting switch closes circuit on increase and opens circuit on decrease in pressure.

O-1401—LOW PRESSURE COMMERCIAL CONTROL. Graduated visible scale with calibrations for range and differential setting. Range screw changes cut-out and cut-in together. Differential screw changes cut-out only.

O-1402—LOW PRESSURE COMMERCIAL CONTROL. Similar to O-1401, but has constant cut-in. Like all Ranco type O Controls, is compact, sturdily constructed and adaptable to individual installation requirements.

O-1419—TEMPERATURE COMMERCIAL CONTROL. Outside range and differential (cut-out) adjustments with graduated visible scales and calibrations. Lowest cut-out: F.; highest cut-in: 15° F.

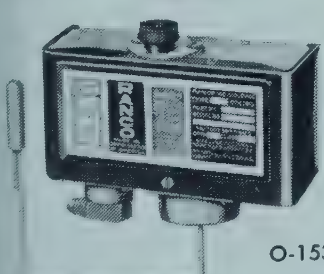
O-1402



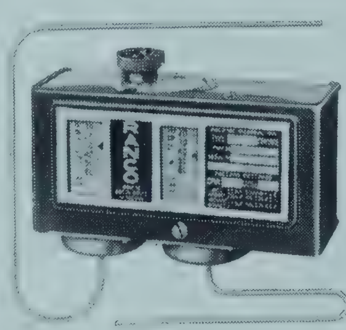
O-1419

TYPE 91-O—EXCLUSIVE INTERLOCKING TWO-TEMPERATURE CONTROL. Assures uniform temperature, uniform high relative humidity and completely automatic defrosting of coil regardless of weather or load conditions or cold location of the compressor.

O-1535—DUAL TEMPERATURE COMMERCIAL CONTROL. Range screw changes temperature cut-out and cut-in together. High pressure cut-out independently adjustable. Differential screw changes temperature cut-out only.



O-1535



91-O

Ranco Inc. RANCO CONTROLS

Available Through Leading Wholesalers

WRITE FOR INFORMATION

CONTROLLERS, FLOW (See REGULATORS, FLOW)

CONTROLLERS, PRESSURE (See REGULATORS, PRESSURE)

CONTROLLERS, STARTING LOAD

Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*

CONTROLLERS, TEMPERATURE (See REGULATORS, TEMPERATURE)

CONVERTERS, ELECTRICAL (See RECTIFIERS)

CONVEYORS & COMPONENTS (See also CHAIN; also PULLEYS; also SPROCKETS, etc.)

Ajax Flexible Coupling Co., Inc., Westfield, N.Y. (Vibrating)
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Alvey-Ferguson Co., Oakley Sta., Cin'ti., O.
American Monorail Co., 13107 Athens Ave., Cleveland 7, O.
Audubon Wire Cloth Corp., Richmond St. & Castor Ave., Phila. 34, Pa. (Wire Belt)
Baldwin Duckworth Div., Chain Belt Co., 360 Plainfield St., Springfield, Mass.
C. O. Bartlett & Snow Co., 6200 Harvard Ave., Cleveland 5, O.
Beverage Engrg. & Equip. Co., 13301 Lakewood Hts. Blvd., Cleveland 7, O.
Bonded Scale Co., 2176 S. 3rd St., Columbus 7, O.
Brady Conveyors Corp., 20 W. Jackson Blvd., Chicago 4, Ill.
E. W. Buschman, Inc., 4400 Clifton Ave., Cin'ti. 32, O.
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
Cleaver-Brooks Co., 326 E. Keefe Ave., Milwaukee 12, Wis.
Cleveland Crane & Engrg. Co., Wickliffe, O. (Overhead)

Conveyor Co., 3260 E. Slauson Ave., Los Angeles 11, C
H. N. Cook Belting Co., 401 Howard St., San Francisco Cal.
Cyclone Fence Div., American Steel & Wire Co., U. Steel Corp., Subsidiary, P.O. Box 260, Waukegan Ill.
R. & J. Dick Co., Inc., 24 Sade St., Passaic, N.J.
Dodge Mfg. Co., 505 S. Union St., Mishawaka, Ind.
Economy Power Engrg. Co., 2030 Washington St., Kans City 8, Mo.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, I
Gifford-Wood Co., Hill St., Hudson, N.Y.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Island Equip. Corp., 101 Park Ave., N.Y.C. 17
Jeffrey Mfg. Co., 887 N. 4th St., Columbus 16, O.
Lamson Corp., Syracuse 1, N.Y.
Link-Belt Co., 300 Pershing Rd., Chicago 9, Ill.
Morse Chain Co., Div. of Borg-Warner Corp., Ithac N.Y.
Mound Tool Co., 1203 S. 7th St., St. Louis 4, Mo.
Norma-Hoffman Bearings Corp., Hamilton Ave., Star ford, Ct.
Samuel Olson Mfg. Co., Inc., 2418 Bloomingdale R Chicago 47, Ill.
Palmer-Bee Co., 1701 Poland Ave., Detroit 12, Mich.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 2 Pa. (Belting only)
Raybestos-Manhattan, Inc., 61 Willett St., Passaic. N.
Read Machinery Div., Standard Stoker Co., Inc., Yor Pa.
Shaw-Box Crane & Hoist Div., Manning, Maxwell Moore, Inc., Muskegon, Mich.
Stephens-Adamson Mfg. Co., Ridgeway Ave., Aurora, I
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, I (Guards)
Wickwire Spencer Steel Div., Colorado Fuel and Ir Corp., 500-5th Ave., N.Y.C. 18

COOLANT COOLERS & COOLANT COOLING SY TEMS (See also OIL COOLERS)

Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton 1,
Richard M. Armstrong Co., Box 188, W. Chester, P *(p. 5*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 4*
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 3 N.Y. *(p. 5*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal
Heat-X-Changer Co., Inc., 415 Lexington Av N.Y.C. 17 *(p. 12*
Niagara Blower Co., 405 Lexington Ave., N.Y.C. *(p. 9*
Read Machinery Div., Standard Stoker Co., Inc., Yor Pa.
Reco Products Div., Refrigeration Engrg. Corp., 20 Naudain St., Phila. 46, Pa.
Ross Heater & Mfg. Co., Div. of American Radiator Standard Sanitary Corp., Buffalo 13, N.Y.
Temprite Products Corp., 47 Piquette Ave., Detro 2, Mich. *(p. 8*
Young Radiator Co., Racine, Wis. *(p.*

COOLERS (See particular type)

COOLING PONDS

Binks Mfg. Co., 3114 Carroll Ave., Chicago 16, Ill.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal
Marley Co., Inc., 3001 Fairfax Rd., Kansas City 1 Kan. *(p. 7*
Jos. A. Martocello & Co., 229 N. 14th St., Phila. Pa. *(p. 14*
Phillips Cooling Tower Co., Inc., 114 Liberty St., N.Y. 6
Reco Products Div., Refrigeration Engrg. Corp., 20 Naudain St., Phila. 46, Pa.
Spray Engrg. Co., 114 Central St., Somerville 45, Mas
Spraying Systems Co., 3201 Randolph St., Bellwood, Cl cago, Ill.
Thermal Industries, P.O. Box 725, Indio, Cal.
Water Cooling Corp., 71 Nassau, N.Y.C. 7
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.
York Corp., York, Pa. *(p. 16*

COOLING TOWERS

Acme Equip. Co., 205 E. Broadway, Muskogee, Okla.

(Continue

COOLING TOWERS (Continued)

Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
American Cooling Tower Co., 2710 McGee St., Kansas City 8, Mo.
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Belcher-Young, 500 S. Packwood, Tampa, Fla.
Binks Mfg. Co., 3114 Carroll Ave., Chicago 16, Ill.
Continental Air Filters, Inc., 2520 Helm St., Louisville, Ky.
Fluor Corp., Ltd., 2500 S. Atlantic Blvd., Los Angeles 22, Cal.
Foster Wheeler Corp., 165 Broadway, N.Y.C.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Harry Cooling Towers, Inc., West St., Doylestown, Pa. *(p. 74)*
Kennard Corp., 1819 S. Handley Rd., St. Louis 17, Mo. *(p. 72)*
Larkin Coils, 519 Memorial Drive, S.E., Atlanta 1, Ga. *(p. 209)*
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
Lilie-Hoffmann Cooling Towers, Inc., 4239 Duncan Ave. St. Louis 10, Mo.
Marley Co., Inc., 3001 Fairfax Rd., Kansas City 15, Kan. *(p. 75)*
Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. *(p. 205)*
Jos. A. Martocello & Co., 229 N. 14th St., Phila. 7, Pa. *(p. 147)*
D. J. Murray Mfg. Co., 1002-3rd St., Wausau, Wis.
New England Cooling Tower Co., 89 Broad St., Boston 10, Mass.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Phillips Cooling Tower Co., Inc., 114 Liberty St., N.Y.C. 6
J. F. Pritchard & Co., 2200 Fidelity Bldg., Kansas City 6, Mo. *(p. 73)*
Reco Products Div., Refrigeration Engrg. Corp., 20 Naudain St., Phila. 46, Pa.
Refrigeration Economics Co., Inc., 1231 E. Tuscar was St., Canton 4, O. *(p. 20*
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimo 24, Md.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinn Heating & Ventilating Co., Inc., 1948 N. 9th St., S Louis 6, Mo.
Spraying Systems Co., 3201 Randolph St., Bellwood, Ch cago, Ill.
Thermal Industries, P.O. Box 725, Indio, Cal.
Trane Co., La Crosse, Wis. *(p. 1*
Typhoon Air Conditioning Co., Inc., Div. of Ice Air Con ditioning Co., Inc., 794 Union St., Brooklyn 15, N.Y
United Conditioning Corp., 74 Varick St., N.Y.C. 13
Water Cooling Corp., 71 Nassau St., N.Y.C. 7
Water Cooling Equip. Corp., Afton Sta., St Louis 23, M
C. H. Wheeler Mfg. Co., 1741 Sedgley Ave., Phila. 32, P
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 11*
York Corp., York, Pa. *(p. 11*

COPPER (See particular mill forms, i.e., BAR SHEET, etc.)

COPPERSMITHING

Arthur Harris & Co., 210 N. Aberdeen St., Chicago 7, Il
Jos. Kopperman & Sons, 312 New St., Phila. 6, Pa.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.

CORDS, ELECTRIC (See WIRE, ELECTRIC; als WIRING DEVICES)

CORK (See INSULATION)

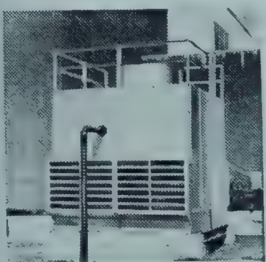
CORROSION INHIBITORS (See INHIBITORS CORROSION)

The Marley Company, Inc.

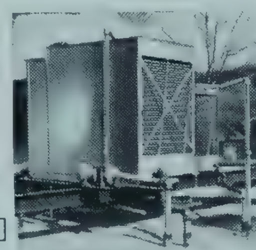
Fairfax and Marley Roads, **Kansas City 15, Kansas**

Representatives in All Principal Cities (Consult Classified Phone Directory)

Water Cooling Towers and DriCoolers of All Types and Capacities. Spray Nozzles

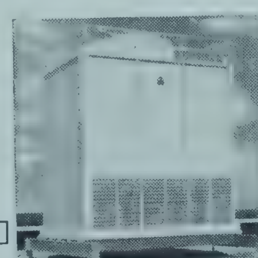


MARLEY Vairflo . . . Sets a new "extra quality" standard for air conditioning and refrigeration cooling towers at no extra cost. Available in choice of steel, wood or asbestos board casing. Has many features formerly found only on heavy duty industrial cooling towers. 25–750 tons of refrigeration. Write for Bulletin V-50.



MARLEY Aquatower . . . For "packaged" cool water, the steel Marley Aquatower packs solid performance for those extra tough jobs. Requires no field erection, is completely assembled, ready to go. Shipped immediately from stock. Aquatower ranges from 3 to 50 tons of refrigeration and is available in eight sizes. Write for Bulletin AQ-50.

MARLEY Natural Draft . . . made of heart quality redwood and available in two models. Economical to erect and operate, sturdy and long lasting. Assures top performance. *Series* 100 . . . used primarily for refrigeration and air conditioning small buildings, theaters, locker plants ranging up to 35 tons of refrigeration. *Series* 200 . . . is built in standardized units for larger capacities and is also available with atmospheric sections for indirect cooling of jacket water, oils and gases. Write for Bulletins 100-50 or 200-50.



MARLEY Conventional . . . Marley conventional COUNTER-FLOW towers assure peak performance and operating economy. Built to high structural standards, they are equipped with Marley mechanical units and other exclusive Marley features. Marley Conventional towers meet every water cooling application and are also adaptable to indirect cooling with atmospheric sections. Available in redwood, steel or asbestos board casing. Medium to large capacity. Write for Bulletin C-50.

MARLEY Double-Flow . . . Has these advanced features in cooling tower design: Horizontal air-flow through full height louver walls, Open distribution system, Low pumping head, Minimum draft loss, Double service from each fan unit, Patented, nail-less filling which retains correct alignment without fasteners, Marley designed and built mechanical equipment, Utmost flexibility, Safe operation and low maintenance cost. Available in redwood or asbestos board casing. Double-flows are used wherever large gallonage of water must be cooled economically and efficiently. Write for Bulletin DF-50.

MARLEY Nozzles . . . Marley patented, bronze Spray Nozzles achieve the fundamental requirement of every spray installation . . . a maximum breakup at lowest pressure . . . without moving parts. Three styles, one piece, two piece, humidifying. Write for Bulletin SN3-50.

COTTER PINS

Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Lamson & Sessions Co., 1971 W. 8th St., Cleveland 2, O.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

COUNTING & COMPUTING DEVICES

Veeder-Root, Inc., Garden & Sargeant Sts., Hartford 2, Ct.

COUPLINGS, ELECTROMAGNETIC

Elliott Co., Jeanette, Pa.

COUPLINGS, PIPE (See FITTINGS, PIPE)

COUPLINGS, MECHANICAL

Centric Clutch Co., 23 South Ave., W., Cranford, N.J.
Dresser Mfg. Div., Dresser Industries, Inc., 490 Fisher Ave., Bradford, Pa.
Gustin-Bacon Mfg. Co., Kansas City 7, Mo.
Hamilton Kent Mfg. Co., Kent. O. (Flexible)
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Philadelphia Gear Wks., Inc., G St. & Erie Ave., Phila. 20 Pa.
Victaulic Co. of America, 30 Rockefeller Plaza, N.Y.C. 20
J. A. Zurn Mfg. Co., Erie, Pa.

COUPLINGS, SELF-SEALING

Paxton-Mitchell Co., 2614 Martha St., Omaha 5, Neb.

COUPLINGS, SHAFT (See SHAFT COUPLINGS)

COVERS, MANHOLE (See ACCESS DOORS)

CRADLES, MOTOR (See BASES)

CRANES & HOISTS

American Monorail Co., 13107 Athens Ave., Cleveland 7, O.
Euclid Crane & Hoist Co., 136 S. Chardon Rd., Euclid 17, O.
Frick Co., Waynesboro, Pa. *(p. 44)*
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Reading Chain & Block Corp., 2100 Adams St., Reading, Pa.
Reco Products Div., Refrigeration Engrg. Corp,. 2020 Naudain St., Phila. 46, Pa.
Reynolds Mfg. Co., Inc., Springfield, Mo.
Shaw-Box Crane & Hoist Div., Manning, Maxwell & Moore, Inc., Muskegon, Mich.
Shepard Niles Crane & Hoist Corp., Schuyler Ave., Montour Falls, N.Y. (Ice)
Union Mfg. Co., New Britain, Ct.

CRANKSHAFTS

Atlas Drop Forge Co., 209 W. Mt. Hope Ave., Lansing 2, Mich.
Modern Machine Wks., Inc., 5355 S. Kirkwood Ave., Cudahy, Wis. *(p. 180)*
Saginaw Malleable Iron Div., Gen'l. Motors Corp., Saginaw, Mich.
J. H. Williams & Co., 400 Vulcan St., Buffalo 7, N.Y.

CUBE MACHINES (See ICE CUBE MACHINES, AUTOMATIC)

CUPS, GREASE & OIL (See GREASE CUPS; also LUBRICATORS)

CYLINDERS, COMPRESSED GAS, REFRIGERANT, etc.

Linde Air Products Co., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Miller Motor Co., 4027 N. Kedzie Ave., Chicago 18, Ill.
Pressed Steel Tank Co., 1471 S. 66th St., Milwaukee 14, Wis. *(p. 77)*
Scaife Co., Oakmont, Pa.

DAIRY REFRIGERATORS (See DISPLAY CASES

DAMPENERS, VIBRATION (See VIBRATION ABSORBERS)

DAMPERS

Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 17
Air Conditioning Products Co., 2340 W. Lafayette Blvd. Detroit 16, Mich.
Air Control Products, Inc., Coopersville, Mich.
Airecon Industries, 2536-14th St., Detroit 16, Mich.
American Warming & Ventilating Co., 1017 Summit St. Toledo 4, O.
Anemostat Corp. of America, 16 E. 39th St., N.Y.C 16 *(p. 19*
Barber-Colman Co., Rockford, Ill.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93*
Corbman Bros., 315 N. 7th St., Phila. 6, Pa.
Elgo Shutter & Mfg. Co., 2735 W. Warren St., Detroit 8 Mich.
Excelsior Steel Furnace Co., 118 S. Clinton St., Chicago 6 Ill.
Hart & Cooley Mfg. Co., 500 E. 8th St., Holland, Mich
Kennard Corp., 1819 S. Hanley Rd., St. Louis 17, Mo *(p. 14*
Ludlow Valve Mfg. Co., Inc., Foot of Adams St., Troy N.Y.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee 3 Wis.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimor 24, Md.
H. H. Robertson Co., 2400 Farmers' Bank Bldg., Pitts burgh 22, Pa.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinne Heating & Ventilating Co., Inc., 1948 N. 9th St., St Louis 6, Mo.
V. E. Sprouse Co., Inc., Columbus, Ind.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y
U. S. Register Co., 344 E. Burnham St., Battle Creek Mich.
Young Regulator Co., 5209 Euclid Ave., Cleveland 3, C

DAMPER MOTORS

Barber-Colman Co., Rockford, Ill.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div. Minneapolis-Honeywe Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I
H. H. Robertson Co., 2400 Farmers' Bank Bldg., Pitts burgh 22, Pa.
Sampsel Time Control, Inc., 600 N. Strong Ave., Sprin Valley, Ill.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y
Young Regulator Co., 5209 Euclid Ave., Cleveland 3, C

DAMPER REGULATORS

Automatic Temperature Control Co., Inc., 5212 Pulask Ave., Phila. 44, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Brown Instrument Co., Div. Minneapolis-Honeywel Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I
Hart & Cooley Mfg. Co., 500 E. 8th St., Holland, Mich
Mason-Neilan Regulator Co., 1190 Adams St., Boston 24 Mass.
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
Sampsel Time Control, Inc., 600 N. Strong Ave., Sprin Valley, Ill.
Schade Valve Mfg. Co., 2527 Bodine St., Phila. 33, Pa.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., New ark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y
Tuttle & Bailey, Inc., New Britain, Ct.
U. S. Register Co., 344 E. Burnham St., Battle Creek, Mich.
Young Regulator Co., 5209 Euclid Ave., Cleveland 3, O

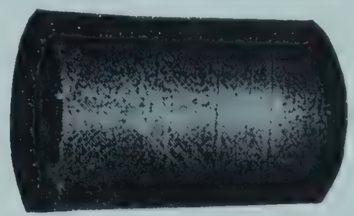
DECORATIONS, METAL (See also NAMEPLATES

American Emblem Co., Inc., 9 Genesee St., New Hart ford, Utica 1, N.Y.
Fox Co., Fox Lane, Cin'ti. 23, O.
Grand Rapids Brass Co., 60 Scribner Ave., N.W., Gran Rapids 1, Mich.

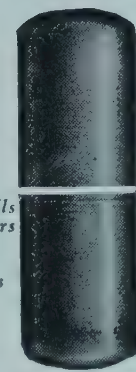
DEEP DRAWN SHAPES AND SHELLS AND CONTAINERS

Hackney Seamless Drawn Shells are ideal for use as condenser shells and refrigerant gas receivers. Efficient performance is due to their smooth surface, elimination of scale, eat appearance, comparative light weight and conomy. Pioneers in the cold drawing of seamless ontainers from metal plates, Pressed Steel Tank Company has had more than 45 years' experience n designing, engineering and manufacturing conainers for gases, liquids and solids. Our engineers vill gladly work with you in developing containrs or special shapes to your individual needs. For ull details, write us today.

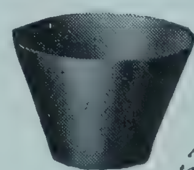
Tapered Diffuser tube, deep-drawn, seamless, 4" x 24"



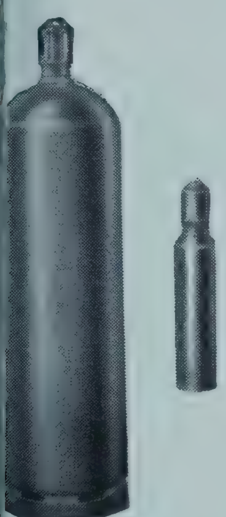
An entirely seamless shell 12" x 20" for 300 lbs. W.P.



Condenser shells or liquid receivers advantageously made by the Hackney Process



A seamless tapered shell



REFRIGERANT COMPRESSED GAS CYLINDERS

Hackney light tare weight cylinders are widely used for anhydrous ammonia, freon, sulphur dioxide, methyl chloride, iso-butane, propane, oxygen, etc.—in capacities from 25 pounds up. They have been designed with the users' requirements in mind—constructed to give full protection to product, ease of handling, utmost resistance to transportation and handling abuse and lowest transportation costs.

Hackney refrigeration cylinders are of two-piece construction or are entirely seamless—formed by a series of cupping cold drawing operations—and subjected to special laboratory controlled heat-treatment, after complete frabrication, to further improve physical qualities. Hackney cold drawing process provides uniform sidewall thickness and eliminates excess material.

All Hackney ICC Cylinders are manufactured to specifications that more than comply with the minimum requirements set up under Interstate Commerce Commission Regulations. Write Pressed Steel Tank Company for full information.

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Pressed Steel Tank Company

Manufacturers of Hackney Products

1483 S. 66th St., Milwaukee 14
1389 Vanderbilt Concourse Bldg., New York 17
231 Hanna Bldg., Cleveland 15

936 W. Peachtree St., N.W., Room 124, Atlanta 3
208 S. La Salle St., Room 2083, Chicago 4
566 Roosevelt Bldg., Los Angeles 14

DEFROSTERS, AUTOMATIC (See CONTROLS, DEFROSTING CYCLE)

DEHUMIDIFIERS, CHEMICAL

Bryant Heater Co., 17825 St. Clair Ave., Cleveland 10, O.
Carbide & Carbon Chemicals Corp., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Drynamic Div., Cargocaire Engrg. Corp., 15 Park Row, N.Y.C. 7
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
W. A. Hammond Drierite Co., 120 Dayton Ave., Xenia, O. *(p. 78)*.
H. J. Kaufman Co., 13215 Roselawn Ave., Detroit 4, Mich.
Surface Combustion Co., 2375 Dorr St., Toledo 1, O.

DEHUMIDIFYING AGENTS (See DEHYDRANTS)

DEHUMIDIFYING SYSTEMS & UNITS

Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 17
American Coils Co., 25 Lexington St., Newark 5, N.J.
Blissfield Mfg. Co., 626 Depot St., Blissfield, Mich.
Bryant Heater Co., 17825 St. Clair Ave., Cleveland 10, O.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Dry Air Products Corp., 734 Jackson Place, Washington 6, D.C.
Drying System, Inc., 1810½ Foster Ave., Chicago 40, Ill.
Drynamic Div., Cargocaire Engrg. Corp., 15 Park Row, N.Y.C. 7
Dryomatic Corp. of America, 1600 Union Ave., Baltimore 11, Md.
Ebco Mfg. Co., 401 W. Town St., Columbus 8, O.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
W. A. Hammond Drierite Co., 120 Dayton Ave., Xenia, O. *(p. 78)*
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
D. J. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
Pittsburgh Lectrodryer Corp., P.O. Box 1766, Pittsburgh 30, Pa.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., Boston 36, Mass. *(p. 16)*
Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.
Tamms Industries, Inc., 228 N. La Salle St., Chicago 1, Ill.
York Corp., York, Pa. *(p. 119)*

DEHYDRANTS

Aluminum Co. of America, Pittsburgh, Pa.
Davison Chemical Corp., Baltimore 3, Md. (Silica Gel) *(p. 79)*
Floridin Co., Warren, Pa.
W. A. Hammond Drierite Co., 120 Dayton Ave., Xenia, O. *(p. 78)*
Highside Chemicals Co., 10 Colfax Ave., Clifton, N.J.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Michigan Alkali Div., Wyandotte Chemicals Corp., Wyandotte, Mich.
Socony Vacuum Oil Co., 26 Broadway, N.Y.C. 4
Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.
Tamms Industries, Inc., 228 N. La Salle St., Chicago 1, Ill.

DEHYDRATORS (See DRIERS)

DELICATESSEN REFRIGERATORS (See DISPLAY CASES)

DEODORIZERS (See ODOR ELIMINATION SYSTEMS)

DESICCANTS (See DEHYDRANTS)

DESICCATORS (See DRIERS)

DIAPHRAGMS

Darcoid Co., Inc., 145-6th Ave., N.Y.C. 13
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Lord Mfg. Co., 1635 W. 12th St., Erie, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Resistoflex Corp., 39 Plansoen St., Belleville 9, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

DIALS, GAUGE, etc. (See NAMEPLATES)

DICHROMATE (See WATER TREATING MATERIALS)

DIE CASTINGS (See CASTINGS, DIE)

DIETHYLENE GLYCOL

Carbide & Carbon Chemicals Corp., Unit of Union Carbide & Carbon Corp., 30. E. 42nd St., N.Y.C. 17

DIFFUSERS, AIR (See AIR DIFFUSERS)

DISCS, COMPRESSOR VALVE (See VALVE DISCS, FLAPPERS, REEDS, etc.)

DISCS, METAL, COMPOSITION, etc.

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Aladdin Heating Corp., 2222 San Pablo Ave., Oakland 12, Cal.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Jenkins Bros., 80 White St., N.Y.C. 13

DISHES, REFRIGERATOR

Corning Glass Wks., Corning, N.Y.
Sneath Glass Co., Hartford City, Ind.
Amos Thompson Corp., Edinburgh, Ind

DISPENSING MACHINES, REFRIGERATED (Se VENDING MACHINES)

DISPLAY CASES, FROZEN FOOD

Ace Cabinet Corp., 110 E. 42nd St., N.Y.C. 17
Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 126*
Anheuser-Busch, Inc., 9th & Wyoming, St. Louis, Mo.
Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, P
Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
Ed Friedrich, Inc., 1117 E. Commerce St., San Antonio Tex.
Hussmann Refrigerator Co., 2401 N. Leffingwell, St Louis 6, Mo. *(p. 81*
Jordan Refrigerator Co., 235 N. Broad St., Phila. 7, P
Kelvinator Div., Nash-Kelvinator Corp., 1425 Plymouth Rd., Detroit, Mich. *(p. 5*
Refrigeration Corp. of America, Div. of Lonergan Mf Co., Inc., Albion, Mich.
Savage Arms Corp., 311 Turner St., Utica 1, N.Y.
Schaeffer, Inc., 801 Washington Ave., N., Minneapolis Minn.
Super-cold Cold Corp., 1020 E. 59th St., Los Angeles, Ca
Tyler Fixture Corp., 1401 Lake St., Niles, Mich. *(p. 8*

DISPLAY CASES, REFRIGERATED

(A—Self-contained; B—With coils but without condensing unit; C—No coils or condensing unit)

American Refrigeration Corp., 2836 Colfax Ave., S., Mi neapolis 8, Minn.
Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 21*
(A) Anheuser-Busch, Inc., 9th & Wyoming, St. Loui Mo.
(B) Bally Case & Cooler Co., Bally, Pa.
(A,B) Bemco Mfg. Corp., 1504 Minor at Pike, Seattle Wash.
(A,B) R. H. Bishop & Co., 103 N. 2nd St., Champaig Ill.
(A) **Carrier Corp., 302 S. Geddes St., Syracuse 1, N.** *(p. 4*
(A,B) Chapman & Wood Refrigeration, 4525 Southwe Pomona, Portland 19, Ore.
(B) Cruse Refrigerator Co., Inc., 504 W. Main St., Loui ville 2, Ky.
(A,B) Delaware Refrigeration Co., 834 N. 6th St., Phil 23, Pa.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(A,B) Federal Refrigerator Mfg. Co., 550 Elizabeth S Waukesha, Wis.
(A,B,C) Fleetwood-Airflow, Inc., 421 N. Penna Av Wilkes-Barre, Pa.
(A,B,C) Fogel Refrigerator Co., 5400 Eadom St., Phil 37 Pa
(A,B) **Frigidaire Div., Gen'l. Motors Corp., Dayto 1, O.** *(p.*
(A,B) Ed Friedrich Sales Corp., 1117 E. Commerce S San Antonio 6, Tex.
(A,B,C) Gem Refrigerator Co., 165 W. Wyoming Av Phila. 40, Pa.
(B) John Herrel & Sons Co., 244 Lear St., Columbus 6,
(A,B) C. V. Hill & Co., Inc., 360 Pennington Ave., Tre ton 1, N.J.
(A) **Hussmann Refrigeration, Inc., 2401 N. Leffin well, St. Louis 6, Mo.** *(p. 8*
(A,B,C) Jordon Refrigerator Co., 235 N. Broad S Phila. 7, Pa.
(A,B) Koch Butchers' Supply Co., 600 E. 14th Ave., Kansas City 16, Mo.
(A,B,C) Jack Langston Co., 3700 Elm St., Dallas 1, Te
(A,B,C) Lingle Refrigerator Co., Inc., 116 E. 15th S Kansas City 6, Mo.
(C) McCall Refrigerator Corp., Hudson, N.Y.
(A,B) McCray Refrigerator Co., Kendallville, Ind.
(A,B) Masterfreeze Corp., Sister Bay, Wis.
(A,B,C) Minneapolis Show Case & Fixture Co., 10 Washington Ave., S., Minneapolis, Minn.
(B) Morton Show Cases, Inc., Washington Courthouse,
John Mowat Refrigerators, 1866 Folsom St., San Fra cisco 3, Cal.
(A,B) Nanticoke Refrigerator Manufacturers, Corner H & Slope Sts., Nanticoke, Pa.
National Refrigerators Co., 827 Koeln Ave., St. Louis Mo.
(A,B,C) Nolin Mfg. Co., Inc., 1100 Madison Ave., Mo gomery 2, Ala.

(Continu

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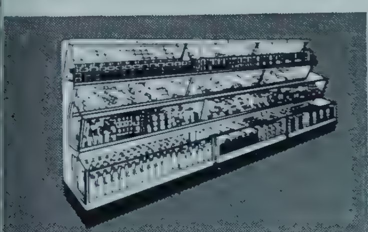
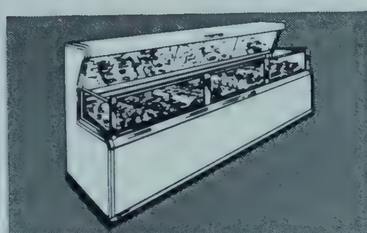
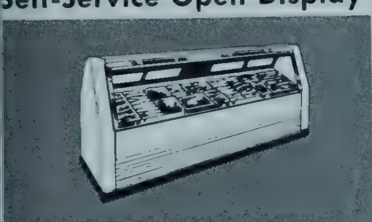
The Name That Stands for Complete Satisfaction

IN FOOD REFRIGERATION EQUIPMENT

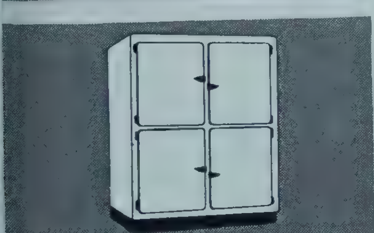




Self-Service Open Display Refrigerators for Dairy, Delicatessen, and Fresh Meats

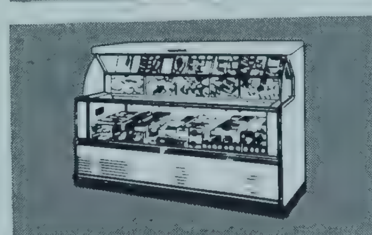


Continuous Top Service Meat Case.

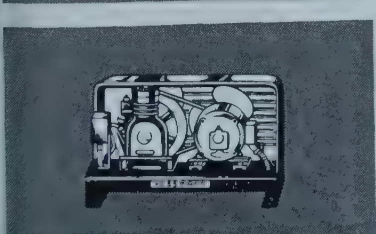
Self-Service Open Display Refrigerator for Produce.



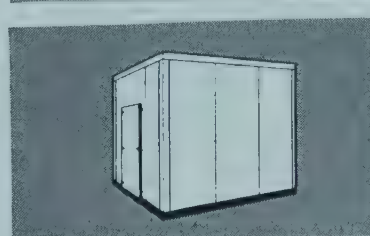
Reach-In-Refrigerators In Many Sizes. Solid Doors or Glass.



Open Self-Service Refrigerator for Frozen Foods.



Condensing Units and Coils in every needed size.



Market Coolers, in sizes to meet every requirement.

Write for full details about the Refrigeration Equipment you are most interested in.

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Ruddy Freeborn Co., Ltd., Brantford, Ont., Hussmann Canadian Subsidiary

DISPLAY CASES (Continued)

C. L. Percival Refrigerator Co., 1805 E. 4th St., Boone, Ia.
(A,B) Puffer-Hubbard Mfg. Co., Grand Haven, Mich.
(A) W. Allen Rogers Industries, Inc., P.O. Box 272, Demopolis, Ala.
(A) Schaefer, Inc., 801 Washington Ave., N., Minneapolis 1, Minn.
(A,B) C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
(B) Schwenger-Klein, Inc., 720 Bolivar Rd., Cleveland, O.
(A,B) Seeger Refrigerator Co., 850 Arcade St., St. Paul 6, Minn.
(A,B) Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
(A,B) Charles Q. Sherman Corp., 149 Broadway, N.Y.C 6
Simplex Mfg. Co., 1135-3rd St., Oakland 20, Cal.
Southern Fixture Mfg. Co., P.O. Box 245, Greensboro, N.C.
(B) Spir-O.Freez Co., Inc., 1077 Castleton Ave., Staten Island 10, N.Y.
(B) Star Metal Mfg. Co., Trenton Ave. & Ann St., Phila. 34, Pa.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(B) Tyler Fixture Corp., 1401 Lake St., Niles, Mich. *(p. 80)*
(A,B,C) Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
(A,B) Viking Refrigerators, Inc., 7500 Wilson Ave., Kansas City 3, Mo.
(A,B,C) Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.
(A,B) Warren Co., Inc., P.O. Box 1436, Atlanta 1, Ga.
(A,B,C) Weber Showcase & Fixture Co., Inc., P.O. Box 2018, Los Angeles 54, Cal.

DISPLAY CASE DOORS & FRAMES

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
Luzerne Rubber Co., Trenton 9, N.J.
McCall Refrigerator Corp., Hudson, N.Y.
Mack Molding Co., Ryerson Ave., Wayne, N.J.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee 3, Wis.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J.
Amos Thompson Corp., Edinburgh, Ind.

DISTRIBUTORS, CONDENSER WATER (See CONDENSER WATER DISTRIBUTORS)

DISTRIBUTORS, REFRIGERANT

Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
Sporlan Valve Co., 7525 Sussex Ave., St. Louis 17, Mo.

DOOR & FRAME ASSEMBLIES (See DISPLAY CASE DOORS or COLD STORAGE DOORS)

DOORS, COLD STORAGE (See COLD STORAGE DOORS)

DOORS, DISPLAY CASE (See DISPLAY CASE DOORS)

DOORS, EVAPORATOR

Aluminum Goods Mfg. Co., Manitowoc, Wis.
Anderson and Sons, Inc., N. Elm St., Westfield, Mass.
Croname, Inc., 3701 N. Ravenswood, Chicago 13, Ill.
Dearborn Glass Co., 2414 W. 21st St., Chicago 8, Ill.
Metal Specialty Co., Este Ave. & B&O R.R., Cin'ti., O.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Sneath Glass Co., Hartford City, Ind.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Amos Thompson Corp., Edinburgh, Ind.

DOORS, FREEZER (See COLD STORAGE DOORS)

DOOR GASKET

Ball Bros. Co., Muncie, Ind.
Brasco Mfg. Co., Harvey, Ill.
Bridgeport Fabrics Co., Bridgeport 1, Ct.
Butcher Boy Cold Storage Door Co., Div. of Western Fixture & Equip. Co., 170 N. Sangamon St., Chicago 7, Ill. *(p. 41)*
Chase Industrial Refrierator Equip. & Engrg. Co., 630 Reading Rd., Reading, Cin'ti. 15, O.
Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
W. J. Dennis & Co., 1732 N. Kolmar Ave., Chicago 39, Ill.
Dryden Rubber Co., 1014 S. Kildare Ave., Chicago 24, Ill.
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Inland Mfg. Div., Gen'l. Motors Corp., Dayton 1, O.
Jamison Cold Storage Door Co., Hagerstown, Md.
Jarrow Products, 420 N. La Salle St., Chicago 10, Ill. *(p. 83)*
Kason Hardware Corp., 127 Wallabout St., Brooklyn 6, N.Y.
Jack Langston Co., 3700 Elm St., Dallas 1, Tex.
Mack Molding Co., Ryerson Ave., Wayne, N.J.
Melrath Supply & Gasket Co., Inc., Tioga & Memphis Sts., Phila. 34, Pa.
Polar Hardware Co., 1631 S. Michigan Ave., Chicago 16, Ill.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Rubatex Div., Great American Industries, Bedford, Va. *(p. 137)*
Sponge Rubber Products Co., 106 Derby Place, Shelton, Ct.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
York Corp., York, Pa. *(p. 119)*

DOUBLE DUTY REFRIGERATORS (See DISPLAY CASES)

DOUGH RETARDERS

(A—Self-contained; B—With coils but without condensing unit; C—No coils or condensing unit)

Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
(A,B) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
(A,B) Cruse Refrigerator Co., Inc., 504 W. Main St., Louisville 2, Ky.
(A,B,C) Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(A,B) Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
(A,B) Fleetwood-Airflow, Inc., 421 N. Penna Ave., Wilkes-Barre, Pa.
(A,B,C) Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.
(A,B) Foster Refrigerator Corp., Mill & N. 2nd Sts., Hudson, N.Y.
(A) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(A,B) Ed Friedrich Sales Corp., 1117 E. Commerce St. San Antonio 6, Tex.
(A,B,C) Gem Refrigerator Co., 165 W. Wyoming Ave., Phila. 40, Pa.
(A,B,C) General Refrigerator & Store Fixtures Co., 856 N. Broad St., Phila., Pa.
(B) John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
(A,B,C) Herrick Refrigerator Co., 1019 Commercial St., Waterloo, Ia. *(p. 170)*

(Continued)

DOOR GASKETS

FOR REFRIGERATORS & COOLING ROOMS

Jarrow Door Gaskets are the approved line for original installation and for replacement. Service men and manufacturers alike prefer them for their quality, economy, and long life. Ninety per cent of all refrigerators and cooling rooms can be fitted with stock Jarrow Gaskets. Your jobber has a complete assortment. Consult us on your special gasket needs

DOOR GASKETS FOR EVERY NEED

Waterproof gaskets for low temperature work in sharp freezers, dry ice cabinets, and store rooms. Will not stick, freeze, or harden. Cushions 3/8" to 5/8" high.

Sponge rubber gaskets with coated fabric covering either regular or grease-proof Cushions from 1/4" to 5/8" high.

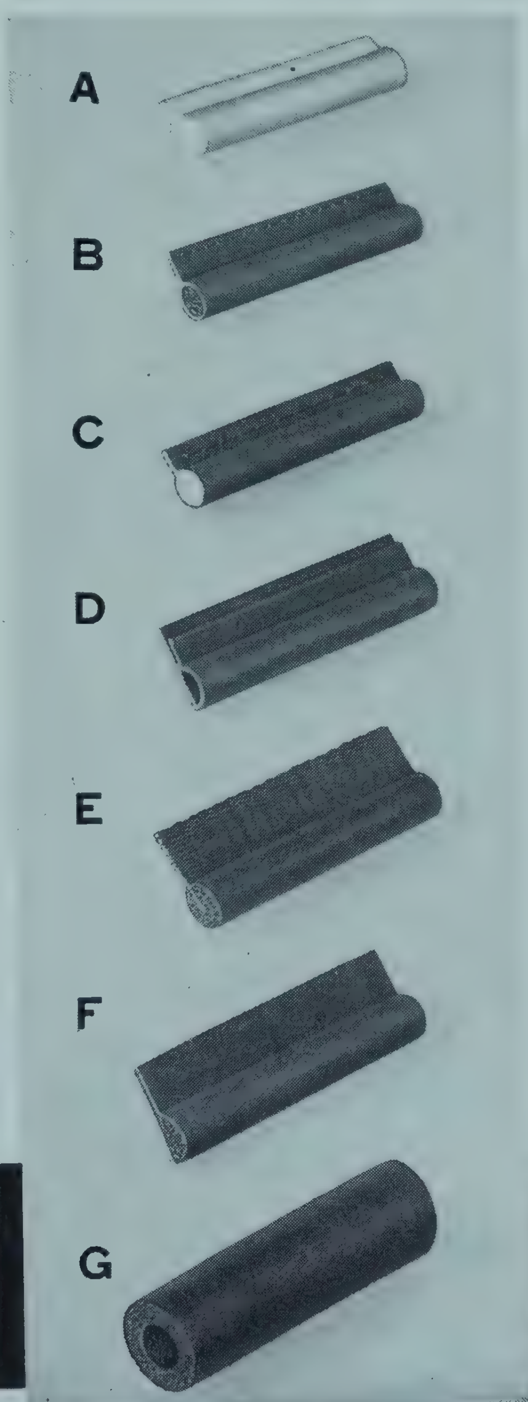
Rubberized fabric door gaskets, with 1/8" to 1" cushion height, any size flanges, in black, white, or maroon with rubberized covering, also grease-proof in black only

Extruded all-rubber gaskets, resilient, grease-resistant, odorless, and non-staining Long-lived black rubber. Any shape or size to fit any make of refrigerator; or to blueprint.

Jarrow Innerseal" gasket; sponge rubber cushion with rubber-covered woven wire flange Neoprene-dipped for grease-resistance Will withstand sub-zero temperatures. Cushions 1/4" to 5/8" high.

Grease-proof rubber gaskets with sponge rubber cushions, sizes 1/4" to 1/2", with rubber on fabric flange. A fine grease-resistant gasket.

G Synthetic sponge rubber tubing, for insulating cold or return compressor lines. Thousands of tiny air cells prevent sweating and loss of efficiency Inside diameters 1/4" to 3/4"



Manufacturers:

Send us your gasket specifications. We make door gaskets and rubber insulation only and are best qualified to consult with you on your gasket problems.

JARROW PRODUCTS

General Office

420 NO. LA SALLE ST., CHICAGO 10

Factories: Chicago and Grand Rapids

DOUGH RETARDERS (Continued)

(A,B) C. V. Hill & Co., Inc., 360 Pennington Ave., Trenton 1, N.J.
(B) Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
(A,B) Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
(A,B) Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
(A,B,C) Jack Langston Co., 3700 Elm St., Dallas 1, Tex.
McCall Refrigerator Corp., Hudson, N.Y.
(A,B) McCray Refrigerator Co., Kendallville, Ind.
(A,B) Masterfreeze Corp., Sister Bay, Wis.
(A,B) Minneapolis Show Case & Fixture Co., 1009 Washington Ave., S., Minneapolis, Minn.
John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
(A,B) Nanticoke Refrigerator Manufacturers, Corner Hill & Slope Sts., Nanticoke, Pa.
(C) J. P. Pfeiffer & Sons, Inc., 200 N. Paca St., Baltimore 1, Md.
(B) Puffer-Hubbard Mfg. Co., Grand Haven, Mich.
(A,B) C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
(B) Schwenger-Klein, Inc., 720 Bolivar Rd., Cleveland, O.
(A,B) Seeger Refrigerator Co., 850 Arcade St., St. Paul 6, Minn.
(B) Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
(A) Charles Q. Sherman Corp., 149 Broadway, N.Y.C.
(B) Star Metal Mfg. Co., Inc., Trenton Ave. & Ann Sts., Phila. 34, Pa.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(A,B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(B) Tyler Fixture Corp., 1401 Lake St., Niles, Mich *(p. 80)*
Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
(B) Viking Refrigerators, Inc., 7500 Wilson Ave., Kansas City 3, Mo.
Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.

AFT ARMS (See FAUCETS)

AFT BEVERAGE COOLERS (See BEER COOLERS, DRAFT)

AWN SHAPES (See SHAPES, DRAWN)

IERS

inco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. (p. 149)
tomatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. (p. 96)
e Products Co., 185 N. Wabansia Ave., Chicago 1, Ill.
ary Valve Co., Melrose Park, Ill. (p. 84)
perial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. (p. 110)
lustrial Wire Cloth Products Corp., Wayne, Mich. (p. 85)
lvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. (p. 59)
nmore Machine Products, Inc., 15 Depew Ave., Lyons, N.Y.
rotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. (p. 213)
dden Brass Products Co., 1111 N. Franklin St., Chicago 10, Ill.
Intire Connector Co., 252 Jefferson St., Newark 5, N.J. (p. 84)
ueller Brass Co., Port Huron, Mich.
mco, Inc., Zelienople, Pa. (p. 107)
orlan Valve Co., 7525 Sussex Ave., St. Louis 17, Mo.
perior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. (p. 85)
abash Mfg. Co., 2300 S. Western Ave., Chicago 8, Ill.
eatherhead Co., 300 E. 131st St., Cleveland 8, O.

RIERS, AIR, FOR BREATHERS

ynamic Div., Cargocaire Engrg. Corp., 15 Park Row, N.Y.C. 7
. A. Hammond Drierite Co., 120 Dayton Ave., Xenia, O. (p. 78)
cIntire Connector Co., 252 Jefferson St., Newark 5, N.J. (p. 84)
ttsburgh Lectrodryer Corp., P.O. Box 1766, Pittsburgh 30, Pa.

RINKING WATER BOTTLES, GLASS

ultiplex Faucet Co., 4325 Duncan Ave., St. Louis 10, Mo.
eath Glass Co., Hartford City, Ind.

RINKING WATER COOLERS, SELF-CONTAINED

oolstream Corp., 157 E. 128th St., N.Y.C.
opeland Refrigeration Corp., Sidney, O. (p. 63)
ordley & Hayes, 541-4th Ave., N.Y.C. 16
ay & Night Mfg. Co., Div. Affiliated Gas Equip. Co., 700 Royal Oaks Ave., Monrovia, Cal.
rayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
bco Mfg. Co., 401 W. Town St., Columbus 8, O.
vans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Fedders Quigan Corp., 57 Tonawanda St., Buffalo 7, N.Y. (p. 53)
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. (p. 6)
General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. (p. 66)
Interstate Engrg. Corp., 2550 E. Imperial Highway, El Segundo, Cal.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. (p. 59)
Perfecold, Inc., 1940 S. Main St., Los Angeles 7, Cal.
Puro Filter Corp. of America, 440 Lafayette St., N.Y.C 3
Star Metal Mfg. Co., Inc., Trenton Ave. & Ann Sts. Phila. 34, Pa.
Sunroc Co., Glen Riddle, Pa. (p. 86)
Tal-Co Mfg. Co., 510 N. Dearborn St., Chicago 10, Ill.
Halsey W. Taylor Co., Warren, O.

(Continued)

DRINKING WATER COOLERS (Continued)

Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*
Westinghouse Elec. Corp., 653 Page Blvd., Springfield 2, Mass.

DRINKING WATER COOLERS, CAFETERIA

Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Cordley & Hayes, 541-4th Ave., N.Y.C. 16
Day & Night Mfg. Co., Div., Affiliated Gas Equip., Inc., 700 Royal Oaks Ave., Monrovia, Cal.
Ebco Mfg. Co., 401 W. Town St., Columbus 8, O.
Fedders-Quigan Corp., 57 Tonawanda St., Buffalo 7, N.Y. *(p. 53)*
Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
Interstate Engrg. Corp., 2250 E. Imperial Highway, El Segundo, Cal.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Perfecold, Inc., 1940 S. Main St., Los Angeles 7, Cal.
Westinghouse Elec. Corp., 653 Page Blvd., Springfield 2, Mass.

DRINKING WATER COOLER FITTINGS, FOUNTAINS, etc.

Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Coolstream Corp., 240 Butler St., Brooklyn 17, N.Y.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Ebco Mfg. Co., 401 W. Town St., Columbus 8, O.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
General Industries Co., Olive & Taylor Sts., Elryia, O.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.

R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
Sunroc Co., Glen Riddle, Pa. *(p. 86)*
Tal-Co Mfg. Co., 510 N. Dearborn Sts., Chicago 10, Ill.
Halsey W. Taylor Co., Warren, O.
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*
Watson-Stillman Co., Roselle, N.J. *(p. 109)*

DRINKING WATER COOLER LOWSIDES (See also WATER COOLERS)

Crandal-Stone Div., Brewer-Titchener Corp., 336 Court St., Binghamton, N.Y.
Day & Night Mfg. Co., Div. Affiliated Gas Equip. Co., 700 Royal Oaks Ave., Monrovia, Cal.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 *(p. 122)*
Interstate Engrg. Corp., 2250 E. Imperial Highway, El Segundo, Cal.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
Sunroc Co., Glen Riddle, Pa. *(p. 86)*
Tal-Co Mfg. Co., 510 N. Dearborn St., Chicago 10, Ill. *(p. 147)*
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*

DRIVES, CHAIN

Baldwin Duckworth Div., Chain Belt Co., 369 Plainfield St., Springfield, Mass.
Link-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind.
Morse Chain Co., Div. of Borg-Warner Corp., Ithaca, N.Y.
Ramsey Chain Co., Inc., 900 Broadway, Albany 1, N.Y.
Simonds Gear & Mfg. Co., 2501 Liberty Ave., Pittsburgh 22, Pa.

VES, FLEXIBLE

gress Drive Div., Tann. Corp., 3750 E. Outer Drive., Detroit 34, Mich.
onds Gear & Mfg. Co., 2501 Liberty Ave., Pittsburgh 22, Pa.
er Mfg. Co., Div. of Dana Corp., 4100 Bennett Rd., Toledo 1, O
. White Dental Mfg. Co., 10 E. 40th St., N.Y.C.

IVES, V-BELT

s-Chalmers Mfg. Co., Milwaukee 1, Wis.
lwin Belting Inc., 85 Chambers St., N.Y.C. 7
wning Mfg. Co., Inc., Maysville, Ky.
gress Drive Div., Tann Corp., 3750 E. Outer Drive, Detroit 34, Mich.
ton Rubber Mfg. Co., 2342 W. Riverview Ave., Dayton 1, O.
& J. Dick Co., Inc., 24 Sade St., Passaic, N.J.
lge Mfg. Corp., 505 S. Union St., Mishawaka, Ind.
es Rubber Co., 999 S. Broadway, Denver 17, Colo.
F. Goodrich Co., 500 S. Main St., Akron, O.
A. Jones Foundry & Machine Co., 4401 Roosevelt Rd., Chicago 24, Ill.
k-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind.
v York Belting & Packing Co., 1 Market St., Passaic, N.J.
Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St Louis 6, Mo.
onds Gear & Mfg. Co., 2501 Liberty Ave., Pittsburgh 22, Pa.
thern Belting Co., 236 Forsythe St., S.W., Atlanta 2, Ga.
rthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

IVES, VARIABLE SPEED

omatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
wning Mfg. Co., Inc., Maysville, Ky.
ngress Drive Div., Tann Corp., 3750 E. Outer Drive, Detroit 34, Mich.
tes Rubber Co., 999 S. Broadway, Denver 17, Colo.
neral Elec. Co., 1 River Rd., Schenectady 5, N.Y.
F. Goodrich Co., 500 S. Main St., Akron, O.
eer Hydraulics, Inc., 454-18th St., Brooklyn 15, N.Y.
na Elec. Motor Co., Findlay Rd., Lima, O.
k-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
k-Belt Co., 2045 W. Hunting Park, Phila. 40, Pa.
w York Belting & Packing Co., 1 Market St., Passaic, N.J.
isbury Motor Div., Wayne Mfg. Co., 1201 Lexington Ave., Pomona, Cal.
entiae Corp., 101 Pine St., Dayton 2, O.
uthern Belting Co., 236 Forsyth St., Atlanta 2, Ga.
estinghouse Elec. Corp., 4454 Genesee St., Buffalo 5, N.Y.

RY ICE (See also CARBON DIOXIDE)

Reduction Sales Co., 60 E. 42nd St., N.Y.C. 17
quid Carbonic Corp., 3100 S. Kedzie Ave., Chicago 23, Ill.
athieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
ttsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.

RY ICE MAKING MACHINERY

arrisburg Steel Corp., P.O. Box 329, Harrisburg, Pa.
ammus Co., 420 Lexington Ave., N.Y.C. 17
ittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
orthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

RYERS (See DRIERS)

RYING EQUIPMENT, AIR OR GASEOUS PHASE

owser, Inc., Terryville, Ct.
rynamic Div., Cargocaire Engrg. Corp., 15 Park Row, N.Y.C. 7
. J. Kaufman Co., 13215 Roselawn Ave., Detroit 4, Mich.

McIntire Connector Co., 252 Jefferson St., Newark 5, N.J. *(p. 84)*
Pittsburgh Lectrodryer Corp., P.O. Box 1766, Pittsburgh 30, Pa.
J. F. Pritchard & Co., 2200 Fidelity Bldg., Kansas City 6, Mo. *(p. 73)*
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

DUCK (See CANVAS)

DUCT ACCESSORIES & FITTINGS (See also QUADRANTS)

Acer & Whedon, Inc., Medina, N.Y.
Acme Mfg. Co., State Rd. below Rhawn St., Holmesburg, Phila., Pa.
Adelta Mfg. Co., Inc., 21st & Ellsworth, Phila. 46, Pa.
Ajax Furnace Fitting Co., Div. of Cincinnati Sheet Metal & Roofing Co., 216 E. Front St., Cin'ti. 1, O.
American Ventilating Hose Co., 15 Park Row, N.Y.C. 7
W. R. Ames Co., 150 Hooper St., San Francisco 7, Cal.
Barber-Colman Co., Rockford, Ill.
Bauer & Black, Div. of the Kendall Co., 2500 S. Dearborn St., Chicago 16, Ill.
Canvas Products Co., 1236 S. 7th St., St. Louis 4, Mo.
Philip Carey Mfg. Co., Lockland, Cin'ti, 15, O.
Corbman Bros., 315 N. 75th St., Phila. 6, Pa.
Excelsior Steel Furnace Co., 118 S. Clinton St., Chicago 6, Ill.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Hart & Cooley Mfg. Co., 500 E. 8th St., Holland, Mich.
Milcor Steel Co., Milwaukee, Wis.
L. J. Mueller Furnace Co., 2005 W. Oklahoma Ave., Milwaukee 7, Wis.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
H. H. Robertson Co., 2400 Farmers' Bank Bldg., Pittsburgh 22, Pa.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
V. E. Sprouse Co., Inc., Columbus, Ind.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
Williamson Heater Co., 216 E. 6th St., Cin'ti. 2, O.

DUCT INSULATION & LINING (See also INSULATION)

Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17 *(p. 135)*
Baldwin-Hill Co., 500 Breuning Ave., Trenton 2, N.J.
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Cork Import Corp., 39 Park Place, Englewood, N.J.
Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Robert A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Masonite Corp., 111 W. Washington St., Chicago, Ill.
Mundet Cork Corp., 7101 Tonnelle Ave., N. Bergen, N.J. *(p. 129)*
National Gypsum Co., 325 Delaware Ave., Buffalo 2, N.Y.
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Taft-Jenkins Co., 27 Sargeant St., Holyoke, Mass.
Grant Wilson, Inc., 316 S. La Salle St., Chicago 4, Ill.
Wood Conversion Co., First Nat'l. Bank Bldg., St. Paul 1, Minn. *(p. 132)*

DUCTWORK PREFABRICATED

Ajax Furnace Fitting Co., Div. of Cincinnati Sheet Metal & Roofing Co., 216 E. Front St., Cin'ti. 2, O.
W. R. Ames Co., 150 Hooper St., San Francisco 7, Cal.
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Corbman Bros., 315 N. 7th St., Phila. 6, Pa.
Excelsior Steel Furnace Co., 118 S. Clinton St., Chicago 6, Ill.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.

(Continued)

DUCTWORK, PREFABRICATED (Continued)

Henry Furnace Co., Medina, O.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee 3, Wis.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
H. H. Robertson Co., 2400 Farmers' Bank Bldg., Pittsburgh 22, Pa.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
Williamson Heater Co., 216 E. 6th St., Cin'ti. 2, O.

DYNAMOTORS

Continental Elec. Co., Inc., 325 Ferry St., Newark 5, N.J.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
Westinghouse Elec. Corp., Lima, O.

EJECTORS (See also STEAM JET)

Croll-Reynolds Engrg. Co., Inc., 17 John St., N.Y.C.
Foster Wheeler Corp., 165 Broadway, N.Y.C.
Tranter Mfg. Co., 105 Water St., Pittsburgh 22, Pa.
Westinghouse Elec. Corp., P.O. Box 7348, S. Phila. 1, Pa.
C. H. Wheeler Mfg. Col, 1741 Sedgley Ave., Phila. 32, Pa.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

ELECTRIC GENERATING PLANTS, DIESEL OR GASOLINE DRIVEN (See also MOTOR GENERATORS)

Bello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.
Buda Co., 154th & Commercial Ave., Harvey, Ill.
Buffalo Gasolene Motor Co., 1 Austin St., Buffalo, N.Y.
Caterpillar Tractor Co., Peoria 8, Ill.
Crocker-Wheeler Div., Joshua Hendy Iron Wks., Ampere, N.J.
Economy Power Engrg. Co., 2030 Washington St., Kansas City 8, Mo.
Electric Machinery Mfg. Co., 1338 Tyler St., N.E., Minneapolis 13, Minn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Hobart Bros. Co., 146 Hobart Square, Troy, O.
LeRoi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Murphy Diesel Co., 5317 W. Burnham St., Milwaukee 14, Wis.
Ready-Power Co., 11231 Freud Ave., Detroit 14, Mich.
Superior Engine Div., National Supply Co., 1401 Sheridan Ave., Springfield, O.
U. S. Motors Corp., 559 Nebrsaka St., Oshkosh, Wis.
Universal Motor Co., 430 Universal Drive, Oshkosh, Wis.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Witte Engine Wks., Div. of Oil Well Supply Co., 1600 Oakland Ave., Kansas City 3, Mo.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

ELECTRIC HEATER ELEMENTS (See HEATER ELEMENTS)

ELECTRICAL WIRING HARNESSES (See WIRING DEVICES)

ELECTRODE COOLING SYSTEMS & COMPONENTS

Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Universal Welder Corp., 735 Carnegie Ave., Cleveland 15, O.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

ELECTRODES, WELDING (See WELDING ELECTRODES & RODS)

ELECTROPLATING SUPPLIES (See also ANODES)

General Scientific Equip. Co., 27th & Huntingdon St., Phila. 32, Pa.
United Chromium, Inc., 51 E. 42nd St., N.Y.C. 17
U. S. Galvanizing & Plating Equip Corp., 27 Heyward St., Brooklyn 11, N.Y.

ELEVATORS, BUCKET (See CONVEYORS)

ELIMINATORS (See particular type, i.e., ODOR SPRAY, VIBRATION ABSORBERS, etc.)

ELLS (See FITTINGS)

EMBLEMS, METAL (See NAMEPLATES)

ENAMEL (See FINISHES)

ENAMEL, BITUMASTIC (See COMPOUNDS MASTIC)

ENAMELING, PORCELAIN (See also NAME PLATES, etc.)

Acromark Co., 5 Morrell St., Elizabeth 4, N.J.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Challenge Stamping & Porcelain Co., Grand Haven 2 Mich.
Chicago Vitreous Enamel Product Co., 1407 S. 55t Court, Cicero 50, Ill.
Fox Co., Fox Lane, Cin'ti. 23, O.
Hussmann Refrigeration, Inc., 2401 N. Leffingwel St. Louis 6, Mo. *(p. 8*
Ingram-Richardson Co., 32nd St., Beaver Falls, Pa.
Ingram-Richardson Co. of Indiana, Frankfort, Ind.
Strong Mfg. Co., Sebring, O.

ENCLOSURES, WIRE (See WIRE FORMING)

ENGINES, BUTANE, GAS, etc.

Atlas Imperial Diesel Engine Co., Oakland, Cal.
Bruce-Macbeth Engine Co., 2111 Center St., N.W., Clev land 13, O.
Buda Co., 154th & Commercial Ave., Harvey, Ill.
Buffalo Gasolene Motor Co., 1 Austin St., Buffalo 7, N.
Clark Bros. Co., Inc., Olean, N.Y.
Continental Motors Corp., Muskegon 82, Mich.
Cooper-Bessemer Corp., Mt. Vernon, O.
LeRoi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Lorimer Diesel Engine Co., 1530 Wood St., Oakland Cal.
McCulloch Motors Corp., 6101 W. Century Blvd., L Angeles 45, Cal.
Sterling Engine Co., 1260 Niagara St., Buffalo 13, N.Y
United Engine Co., W. Holmes Rd., Lansing 12, Mich
Waukesha Motor Co., Waukesha, Wis.
Western Engine Co., Div. of Vernon Tool Co., Ltd., 11 Meridian Ave., Alhambra, Cal.
Worthington Pump & Machinery Corp., Harriso N.J. *(p. 11*

ENGINES, DIESEL

American Locomotive Co., 30 Church St., N.Y.C.
Atlas Imperial Diesel Engine Co., Oakland, Cal.
Baldwin Locomotive Wks., Phila. 42, Pa.
Bolinders Co., Inc., 33 Rector St., N.Y.C.
Buckeye Machine Co., E. O'Connor Ave., Lima, O.
Buda Co., 154th & Commercial Ave., Harvey, Ill.
Busch-Sulzer Bros. Diesel Engine Co., St. Louis 18, M
Caterpillar Tractor Co., Peoria 8, Ill.
Clark Bros. Co., Inc., Olean, N.Y.
Cleveland Diesel Div., Gen'l. Motors Corp., 2160 106th St., Cleveland 11, O.
Continental Motors Corp., Muskegon 82, Mich.
Cooper-Bessemer Corp., Mt. Vernon, O.
Cummins Engine Co., Inc., Columbus, Ind.
Detroit Diesel Engine Div., Gen'l. Motors Corp., 134 W. Outer Dr., Detroit 23, Mich.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicag Ill.
Hooven, Owens, Rentschler Div., General Machin Corp., 545 N. 3rd St., Hamilton, O.
Lima-Hamilton Corp., 545 N. 3rd St., Hamilton, O.
Murphy Diesel Co., 5317 W. Burnham St., Milwaukee Wis.
Niles Tool Wks. Div., General Machinery Corp., 545 3rd St., Hamilton, O.
Nordberg Mfg. Co., 3073 S. Chase Ave., Milwaukee Wis.
Palmer Bros. Engine Co., Cos Cob, Ct.

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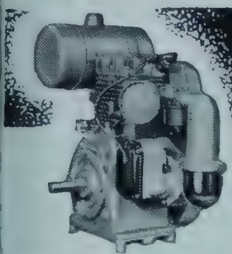
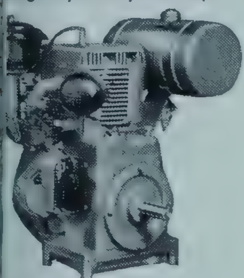
BETTER Engineering Design! ETTER Versatility! BETTER Economy!

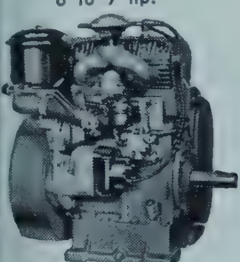
WISCONSIN HEAVY-DUTY Air-Cooled Engines



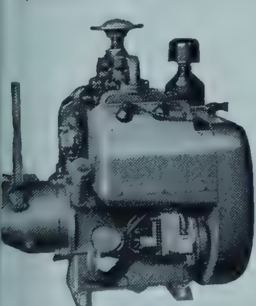
Models ABN and AKN, single cylinder, 3 to 6 hp.



Model AEN 7½ hp. Other Single Cyl. Models 6 to 9 hp.



Models TE and TF,, two-cylinder, 7 to 13 hp.



Models VE-4, VF-4 and VP-4, V-type 4 cylinder, 15 to 30 hp.

Wisconsin Air-Cooled Engines offer the refrigeration equipment manufacturer and power user the cumulative benefits of many years of exclusive specialization in the manufacture of air-cooled engines, in a complete power range from 3 to 30 H.P.

Every Wisconsin Engine, from the smallest to the largest, is of heavy-duty design and construction, built to the highest quality and service standards — to deliver "Most H. P. Hours" of on-the-job power performance.

Every Wisconsin Engine is equipped with tapered roller bearings at BOTH ends of the accurately balanced, drop-forged crankshaft to take up end- and radial thrusts and provide the greatest protection against bearing failure — also permitting safe mounting of drive pulley, gear or sprocket directly on the extended crankshaft.

Every Wisconsin Engine is extremely compact and relatively light in weight for convenient mounting on a great variety of equipment, without costly re-designing or excess weight handicaps.

Every Wisconsin Engine is provided with rotary type high tension OUTSIDE magneto, sealed against dust and moisture, with impulse coupling for quick, easy starting at any temperature, in any weather, assuring thoroughly dependable ignition.

Every Wisconsin Engine gets a 4-hour test (the last hour under full load) before leaving the factory.

SPECIFICATIONS 2- and 4-CYLINDER MODELS

MODEL	TE	TF	VE-4	VF-4	VP-4
Bore	3"	3¼"	3"	3¼"	3½"
Stroke	3¼"	3¼"	3¼"	3¼"	4"
No. of Cylinders	2	2	4	4	4
Displ. Cu. Inches	45.9	53.9	91.9	107.7	154
H. P. and R. P. M. Range	7.2 @ 1400 11.2 @ 2600	8.6 @ 1400 13.2 @ 2600	15 @ 1600 21.5 @ 2400	17.5 @ 1600 25 @ 2400	26.8 @ 1600 31 @ 2200
Net Weight in Lbs. (Standard Engine)	220 (with Side Mount Tank)	220 (with Side Mount Tank)	295	295	410

SPECIFICATIONS, SINGLE CYLINDER MODELS

MODEL	ABN	AKN	AEN	AFH	AGH	AHH
Bore	2½"	2⅞"	3"	3¼"	3½"	3⅝"
Stroke	2¾"	2¾"	3¼"	4"	4"	4"
No. of Cylinders	1	1	1	1	1	1
Displ. Cu. Inches	13.5	17.8	23	33.2	38.5	41.3
H. P. and R. P. M. Range	2.2 @ 1600 4.5 @ 3400	3. @ 1600 5.8 @ 3200	4.4 @ 1600 7.5 @ 3000	6.0 @ 1600 7.2 @ 2200	7.2 @ 1600 8.4 @ 2200	7.7 @ 1600 9.2 @ 2200
Net Weight in Lbs. (Standard Engine)	76	77	110	130	180	180

SPECIAL EQUIPMENT: Variable speed controls, clutch take-off assemblies and reduction assemblies can be furnished on all models. Clutch reduction assemblies and electric starting available for large single cylinder and all two- and four-cylinder models. Special equipment must be specified at time engine is built.

Wisconsin engineers will be glad to work with you in planning your Refrigeration and Conditioner Power installations. Let us have a look at your blueprints and specifications and see what we can come up with.

MOST H.P. HOURS

WISCONSIN MOTOR CORPORATION

World's Largest Builders of Heavy-Duty Air-Cooled Engines

MILWAUKEE 14, WISCONSIN

ENGINES, DIESEL (Continued)

Sterling Engine Co., 1200 Niagara St., Buffalo 13, N.Y.
Superior Engine Div., National Supply Co., 1401 Sheridan Ave., Springfield, O.
United Engine Co.,W. Holmes Rd., Lansing 12, Mich.
Waukesha Motor Co., Waukesha, Wis.
Witte Engine Wks., Div. of Oil Well Supply Co., 1600 Oakland Ave., Kansas City 3, Mo.
Wolverine Motor Wks., Inc., 35 Union Ave., Bridgeport 2, Ct.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

ENGINES, GASOLINE, KEROSENE

Briggs & Stratton Corp., 2711 N. 13th St., Milwaukee 1, Wis.
Continental Motors Corp., Muskegon 82, Mich.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
LeRoi Co., 1706 S. 68th St., Milwaukee 14, Wis.
Novo Engine Co., 702 Porter St., Lansing 5, Mich.
D. W. Onan & Sons, Inc., 498 Royalston Ave., Minneapolis 5, Minn.
Salisbury Motor Div., Wayne Mfg. Co., 1201 Lexington Ave., Pomona, Cal.
Sterling Engine Co., 1260 Niagara St., Buffalo 13, N.Y.
United Engine Co., W. Holmes Rd., Lansing 12, Mich.
Waukesha Motor Co., Waukesha, Wis.
Wisconsin Motor Corp., 1910 S. 53rd St., Milwaukee 14, Wis. *(p. 89)*
Witte Engine Wks., Div. of Oil Well Supply Co., 1600 Oakland Ave., Kansas City 3, Mo.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

ENGINES, STEAM

Ames Iron Wks., Oswego, N.Y.
Hooven, Owens, Rentschler Div., General Machinery Corp., 545 N. 3rd St., Hamilton, O.
Niles Tool Wks. Div., General Machinery Corp., 545 N. 3rd St., Hamilton, O.

Nordberg Mfg. Co., 3073 S. Chase Ave., Milwauke Wis.
Skinner Engine Co., Erie, Pa.
Troy Engine & Machine Co., 400 Railroad Ave., T Pa.
United Engine Co., W. Holmes Rd., Lansing 12, Mich
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wi *(p.*
Worthington Pump & Machinery Corp., Harris N.J. *(p. 1*

ENGINE JACKET-WATER COOLERS

American District Steam Co., Bryant St., N. Tonawan N.Y.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn N.Y. *(p.*
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chic 5, Ill.
Frick Co., Waynesboro, Pa. *(p.*
Trane Co., La Crosse, Wis. *(p.*
Worthington Pump & Machinery Corp., Harris N.J. *(p. 1*

ENGRAVING (See NAMEPLATES)

EQUALIZER TANKS (See SURGE TANKS; also A CUMULATORS)

ESCUTCHEONS (See NAMEPLATES)

ETHYLENE GLYCOL

Carbide & Carbon Chemicals Corp., Unit of Union C bide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Dow Chemical Co., Midland, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington Del.

EVAPORATIVE CONDENSERS

Acme Industries, Inc., Mechanic & Ganson S Jackson, Mich. *(p. 2*
Aerofin Corp., 410 Geddes St., Syracuse, N.Y. *(p.*

(Contin

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anta — Boston — Buffalo — Chicago — Cleveland — Detroit — Kansas City — , Angeles — Montreal — Philadelphia — Pittsburgh — Richmond — Rochester — San Francisco — Seattle — St. Louis

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Type "A"—Bulletin #107
Type "C"—Bulletin #80

AGARA CONTROLLED HUMIDITY METHOD— Bulletin #112

AGARA NO-FROST METHOD— Bulletins #95 and #105

IAGARA SPRAY COOLERS— Bulletin #72, Part 3

IAGARA DUAL COOLERS— Bulletin #70

NIAGARA FAN COOLERS— Bulletin #72, Part 2

NIAGARA AEROPASS CONDENSERS— Bulletin #103

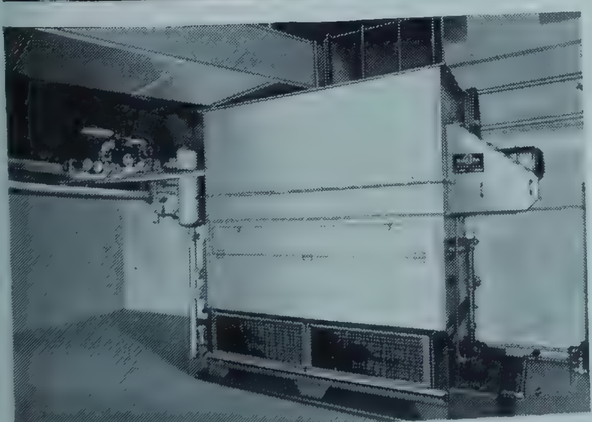
NIAGARA AERO HEAT EXCHANGER— Bulletin #96

NIAGARA STANDARD COIL SECTIONS—Bulletin #92

NIAGARA MOTOR BLOWERS— Bulletin #89, Part 1

NIAGARA AEROPASS CONDENSERS

Refrigeration plant operators, using the Niagara Aeropass Condenser, gain as much as 35% of power by reducing compressor head pressures. This gain is assured permanently because the patent Duo-Pass prevents scale depositing on Condenser tubes. Equipped with the Niagara "Oil-out," a system free from oil is obtained.



NIAGARA "No-Frost" METHOD

For refrigerated rooms below freezing, the Niagara "No-Frost" Method gives always full capacity at lower cost because no ice ever forms on coils. It provides rapid, uniform cooling for products, trouble-free operation and lower operating expenses.

EVAPORATIVE CONDENSERS (Continued)

American Blower Corp., Div. of American Radiator Standard Sanitary Corp., 8111 Tireman Ave., D troit 32, Mich.
American Coils Co., 25 Lexington St., Newark 5, N.J.
American Cooling Tower Co., 2710 McGee St., Kans City 8, Mo.
Baker Refrigeration Corp., S. Windham, Me. (p. 4
Baltimore Aircoil Co., Inc., 715 W. Pratt St., Balt more 1, Md. (p. 9
Betz Corp., 445 State St., Hammond, Ind.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y (p. 9
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y (p. 4
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 3 Cal.
Frick Co., Waynesboro, Pa. (p. 4
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. (p.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
General Elec. Co., Air Conditioning Dept., 5 Law rence St., Bloomfield, N.J. (p. 6
General Refrigeration Div., Yates-American Ma chine Co., Beloit, Wis. (p. 5
Harry Cooling Towers, Inc., West St., Doylestown Pa. (p. 7
Howe Ice Machine Co., 2825 Montrose Ave., Chicag 18, Ill. (p. 4
Kennard Corp., 1819 S. Hanley Rd., St. Louis 17, M (p. 9
Kramer Trenton Co., Olden & Breuning Aves Trenton 5, N.J. (p. 20
Larkin Coils, 519 S. Memorial Dr., S.E., Atlanta Ga. (p. 20
Marlo Coil Co., 6135 Manchester Ave., St. Louis 1 Mo. (p. 20
C. F. Moores Co.. Inc., 1123 Ivy Hill Rd., Wyndmo Phila. 18, Pa.
Niagara Blower Co., 405 Lexington Ave., N.Y.C. 1 (p. 9
J. F. Pritchard & Co., 2200 Fidelity Bldg., Kans City 6, Mo. (p. 7
Reco Products Div., Refrigeration Engrg. Corp., 20 Naudain St., Phila. 46, Pa.
Refrigeration Appliances, Inc., 917 W. Lake St., Chica 7, Ill.
Refrigeration Economics Co., Inc., 1231 E. Tu carawas St., Canton 4, O. (p. 20
Refrigeration Engrg., Inc., 7250 E. Slauson Av Los Angeles, Cal. (p. 21
Edw. Renneburg & Sons Co., 2639 Boston St., Baltim 24, Md.
R. E. Ristow, 2228 S. Atlantic Blvd., Los Angeles 22, C
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, C
B. F. Sturtevant Div., Westinghouse Elec. Cor 101 Readville St.,, Boston 36, Mass. (p. 1
Trane Co., La Crosse, Wis. (p. 1
Typhoon Air Conditioning Co., Inc., Div. of Ice Air Co ditioning Co., Inc., 794 Union St., Brooklyn 15, N.
U. S. Air Conditioning Corp., Como Ave., S.E., at 33 St., Minneapolis 14, Minn.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis (p. 4
Worthington Pump & Machinery Corp., Harriso N.J. (p. 11
York Corp., York, Pa. (p. 11
Young Radiator Co., Racine, Wis. (p.

EVAPORATIVE COOLERS (See ATMOSPHER COOLERS)

EVAPORATORS (See COILS, UNIT COOLERS, et

EVAPORATORS, HOUSEHOLD REFRIGERATO

R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Bohn Aluminum & Brass Corp., E. Maumee, Adri Mich.
Heintz Mfg. Co., Front St. & Olney Ave., Phila. 20,
Houdaille-Hershey Corp., 1900 Foss Park Ave., Chicago, Ill. (p.
Kelvinator Div., Nash-Kelvinator Corp., 14 Plymouth Rd., Detroit, Mich. (p.
Kenmore Machine Products, Inc., 15 Depew Ave., Lyo N.Y.

(Contin

EVAPORATORS, HOUSEHOLD REFRIGERATOR (Continued)

Kold-Hold Mfg. Co., 735 E. Hazel St., Lansing 4, Mich.
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
Rudy Mfg. Co., Dowagiac, Mich.
Standard Refrigeration Co., 232 S. Hoyne Ave., Chicago, 20, Ill.

EXCHANGERS, HEAT (See HEAT EXCHANGERS)

EXPANDED METAL (See MESH, METAL)

EXPANSION JOINTS

American District Steam Co., Bryant St., N. Tonawanda, N.Y.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago Metal Hose Corp., Maywood, Ill.
Cleveland Coppersmithing Wks., 5500 Stone Ave., Cleveland 2, O.
Cook Elec. Co., 2700 Southport Ave., Chicago 14, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill. *(p. 105)*
Croll-Reynolds Engrg. Co., Inc., 17 John St., N.Y.C.
Dresser Mfg. Div., Dresser Industries, Inc., 490 Fisher Ave., Bradford, Pa.
Arthur Harris & Co., 210 N. Aberdeen St., Chicago 7, Ill.
Joseph Kopperman & Sons, 312 New St., Phila. 6, Pa.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.
J. A. Zurn Mfg. Co., Erie, Pa.

EXPANSION VALVES, AUTOMATIC
(A—Ammonia; B—Methyl Chloride; —Sulfur; D—Freon)

(A,B,C,D) Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
(B,C,D) Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
(A) Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
(A,B,C,D) A. W. Cash Co., 540 N. 18th St., Decatur, Ill.
(B,C,D) Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
(B,C,D) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(A) General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. *(p. 58)*
(A,B,C,D) Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
(B,C,D) Mayson Mfg. Co., Inc., 4332 Horatio St., Detroit 10, Mich.
(A,B,D) Refrigerating Specialities Co., 728 Sacramento Blvd., Chicago 12, Ill.
(A) Sporlan Valve Co., 7525 Sussex Ave., St. Louis 17, Mo.
(A,B,D) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,D) York Corp., York, Pa. *(p. 119)*

EXPANSION VALVES, HAND OR NEEDLE
(A—Ammonia; B—Other refrigerants)

(A) Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill. *(p. 105)*
(A) Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
(A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
(A,B) Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
(A,B) Henry Valve Co., Melrose Park, Ill. *(p. 212)*
(B) Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
(B) Mueller Brass Co., Port Huron, Mich.
(B) Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 214)*
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(A) Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
(A,B) Watson-Stillman Co., Roselle, N.J. *(p. 109)*
(B) Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
(A,B) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
(A,B) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,B) York Corp., York, Pa. *(p. 119)*

EXPANSION VALVES, SPECIAL LOW TEMPERATURE
(A—Ammonia; B—Other refrigerants)

(A,B) Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
(B) Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
(B) Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
(A,B) Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
(B) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(A,B) Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
(B) Sporlan Valve Co., 7525 Sussex Ave., St. Louis 17 Mo.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(B) Wittenmeier Machinery Co., 850 N. Spaulding Ave Chicago 51, Ill.
(A) XL Refrigerating Co., 1834 W. 59th St., Chicago 36 Ill.

EXPANSION VALVES, THERMOSTATIC
(A—Ammonia; B—Methyl Chloride; C—Sulfur; D—Freon)

(A,B,C,D) Alco Valve Co., 855 Kingsland Ave., St Louis 5, Mo. *(p. 95)*
(B,C,D) Automatic Products Co., 2450 N. 32nd St Milwaukee 10, Wis. *(p. 96)*
(B,C,D) Detroit Lubricator Co., 5900 Trumbull Ave Detroit 8, Mich.

(Continued)

American Standard Safety Code for Mechanical Refrigeration (ASA-B9.1-1950), is now available at $1.00 the copy.

Sponsored by the American Society of Refrigerating Engineers, it is the result of years of effort on the part of ASA Sectional Committee B9 and several subcommittees.

Most of the refrigeration-producing equipment, household, commercial, or industrial, is manufactured by companies whose business is nationwide. It is, therefore, desirable that this Code be universally adopted so that safety provisions for refrigerating installations will be standardized.

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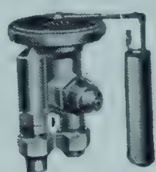
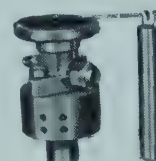
RMO EXPANSION VALVES: for automatic control of liquid refrigerant on all types efrigeration and air conditioning systems. Capacities—from fractional tonnage to 100 Methyl Chloride, 50 tons "Freon-12".

Type 402



Type TK—
"3 valves in 1"

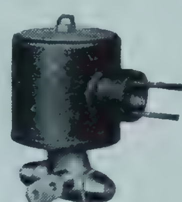
Type TCL



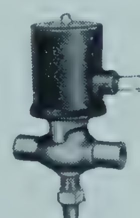
Type TR—
Multi-Outlet

CO SOLENOID VALVES

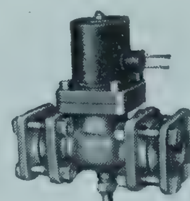
LENOID VALVES: for all es of service. For Liquid: eon"—up to 75 tons. Methyl oride—up to 150 tons. For tion: "Freon"—up to 8.8 s. Methyl Chloride—up to ons.



Type S1



Type M3

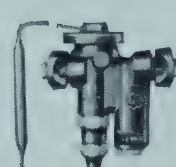


Type R2

CO AMMONIA CONTROLS

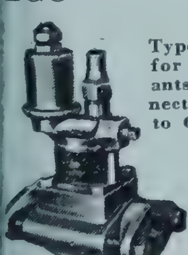
IMONIA CONTROLS: Solenoid Liquid lves—up to 172 tons. Solenoid Suction lves—up to 28 tons. Thermo Expansion lves—from fractional tonnage to 60 tons.

Type M9F

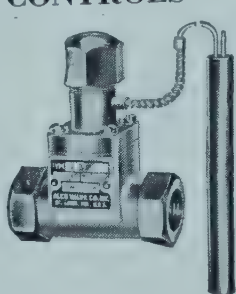


Type UG

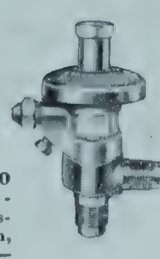
CO SUCTION LINE CONTROLS



Type EPR13—for all refrigerants, with connection sizes up to 6 in.



Type 732 SNAP-ACTION SUCTION VALVE—Temperature—½ ton, "Freon-12"—1 ton, Methyl Chloride.



Type 760 "EVAPOTROL"—Pressure—½ ton, "Freon-12"—¾ ton, Methyl Chloride.

LCO also makes: Solenoid Valves for brine, water, gas, air and steam—Float Switches—igh Pressure Float Valves—Constant Pressure Expansion Valves—Liquid and Suction ine Strainers.

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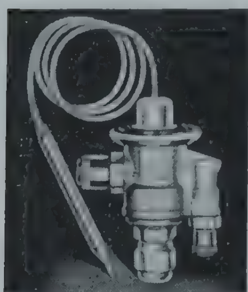
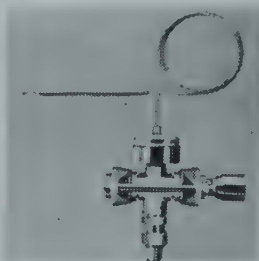
Milwaukee 10 Wisconsin

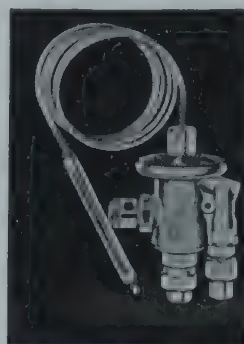
A-P Air Conditioning and Refrigeration Contro



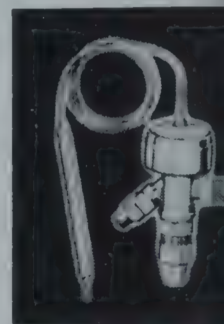
A-P Model 207
Maximum Capacity,
1 ton Freon



A-P Model 216, with Pressure Limiting Feature. Available with "Equa-Flo" Distributors. Capacity, to 11 tons Freon.

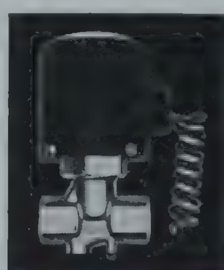


A-P Model 205-C.
Maximum Capacity,
2½ tons Freon.

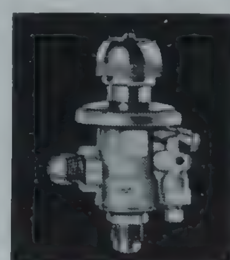


A-P Model 212 The mostatic Expansio Valve. Pressure Limi ing feature. Adjus able. Capacity to ton Freon. Model 21 Non-adjustable.

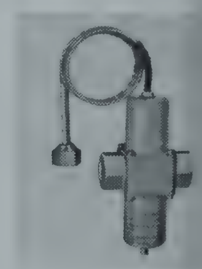
A-P Model 204-C. Automatic Expansion Valve. Calibrated Adjusting Scale. Nominal Capacity, ½ ton Freon.



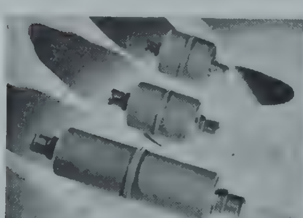
A-P Solenoid No. 73RJX Multi-Purpose, for water, refrigerants, oil, gas. Cap., 12.5 tons Freon or 606 G.P.H.



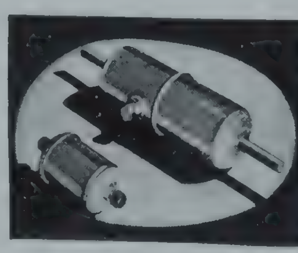
A-P Constant Suction Pressure Regulating Valve No. 235-S. Sensitive, with adjusting knob, graduated pressure scale.



A-P Water Regulat Valve No. 65. S cleaning, non-cloggi



A-P "TRAP-IT"
Positive System-Protection
against impurities.



A-P "TRAP-DRI"
Capacities up to 5 tons; some are rechargeable type. 100% protection because it is a DRIER, STRAINER and FILTER.

A-P DEPENDABLE Refr eration Valves widely used refrigeration and air con tioning systems of all sizes a types, are well-known for th durability, long-life efficien and accuracy in refrigera control. Their reputation f DEPENDABILITY is bas on long experience and know edge in designing and en neering the kind of valves t help make every installati completely satisfactory in c erating efficiency. *Write f latest Catalog.*

DEPENDABLE
REFRIGERANT VALVES

NSION VALVES, THERMOSTATIC (Con- d)

)) **Frigidaire Div., Gen'l. Motors Corp., Dayton O.** *(p. 6)*

)) **General Controls Co., 801 Allen Ave., Glen- ale 1, Cal.** *(p. 67)*

)) Mayson Mfg. Co., Inc., 4332 Horatio St., De- oit 10, Mich.

)) Peerless of America, Inc., 2901 Lawrence Ave., hicago 25, Ill.

C,D) Sporlan Valve Co., 7525 Sussex Ave., St. Louis 7, Mo.

Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.

D) XL Refrigerating Co., 1834 W. 59th St., Chi- ago 36, Ill.

OLTS

Williams & Co., 400 Vu can St., Buffalo 7, N.Y.

S (See also BLOWERS)

Equip. Co., 205 E. Broadway, Muskogee, Okla.
nce Fan & Blower Co., 3428 Bagley, Detroit, Mich.
ent Fan Co., 710 E. Ash St., Piqua, O.
ontrols, Inc., Div. of Cleveland Heater Co., 2310 Su- erior Ave., Cleveland 14, O.
aster Corp., 4317 Ravenswood Ave., Chicago 13, Ill.
lin Heating Corp., 2222 San Pablo Ave., Oakland 12, Cal.
Ventilator Div., Production Planning Co., 704 Woodward, Rochester, Mich.
aloyn Engrg. Co., 220 Seville, Fontana, Cal.
ican Blower Corp., Div. of American Radiator & Standard Sanitary Corp., 8111 Tireman Ave., De- troit 32, Mich.
ican Coolair Corp., 3606 Mayflower St., Jackson- ville, Fla.
Co., 333 N. Michigan Ave., Chicago 1, Ill.
ey Blower Co., 66th & Burnham Sts., Milwaukee 14, Wis.
op & Babcock Mfg. Co., 4901 Hamilton Ave., N.E., Cleveland 14, O.
Blazer & Son, 173 Market St., Passaic, N.J.
alo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
Mfg. Co., 932 S. High St., Akron 11, O.
H Air Conditioning Fan Co., Inc., 1603 DeKalb Ave., N.E., Atlanta, Ga.
ury Fan Ventilator Co., 47 Cedar St., Stamford, Ct.
mpion Blower & Forge Co., Harrisburg & Charlotte Sts., Lancaster, Pa.
lsea Fan & Blower Co., Inc., 1206 S. Grove St., Irvington 11, N.J. *(p. 97)*
ago Blower Corp., 4588 W. Congress St., Chicago 24, Ill.
age Fan Co., Porter St., Kalamazoo 16, Mich.
Bothezat Fans, Div. of American Machine & Metals, Inc., E. Moline, Ill.
ilbiss Co., 300 Phillips Ave., Toledo 1, O.
hl Mfg. Co., 1152 Finderne Ave., Somerville, N.J.
l-Air Fan Co., P.O. Box 169, S. Elgin, Ill.
iron Co., Inc., Dayton 1, O.
le-Picher Sales Co., American Bldg., Cin'ti 1, O.
trovent Fan & Mfg. Co., 812 W. Lake St., Chicago 7, Ill.
erson Elec. Mfg. Co., 8100 Florissant Ave., St. Louis 21, Mo.
co Industries, Inc., Union & Augusta Sts., Rochester 2, N.Y.
den City Fan Co , 332 S. Michigan Ave., Chicago 4, Ill.
eral Elec. Co., 1 River Rd., Schenectady 5, N.Y
ettl Bros. Metal Products, Inc., 714 S. Central, Phoe- nix, Ariz.
rtzell Propeller Fan Co., Div. of Castle Hills Corp., 910 S. Downing St., Piqua, O.
Elec. & Ventilating Co., 2850 N. Crawford Ave., Chi- cago 41, Ill.
frey Mfg. Co., 887 N. 4th St., Columbus 16, O.
nson Fan & Blower Corp., 1318 W. Lake St., Chicago 7, Ill.
Mfg. Co., Oliver Bldg., Pittsburgh 22, Pa.
lvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
ng Co., 902 N. Cedar St., Owatonna, Minn
u Blower Co., 2007 Home Ave., Dayton 7, O.
arathon Elec. Mfg. Corp., Wausau, Wis.
artin Fan & Blower Co., 4634 W. 21st Place, Chicago 50, Ill.

(Continued)

FANS (Continued)

Meier Elec. & Machine Co., 3525 E. Washington, Indpls. 7, Ind.
Moore Co., 544 Westport Rd., Kansas City 2, Mo.
National Engrg. & Mfg. Co., 519 Wyandotte St., Kansas City 6, Mo.
Herman Nelson Corp., 1824-3rd Ave., Moline, Ill.
Northern Blower Co., W. 65th St., South of Denison, Cleveland 2, O.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Peerless Elec. Co., 2000 W. Market St., Warren, O.
Piqua Machine & Mfg. Co., Young & College Sts., Piqua, O.
J. F. Pritchard & Co., 2200 Fidelity Bldg., Kansas City 6, Mo. *(p. 73)*
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
Robinson Ventilating Co., Zelienople, Pa.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Schwitzer-Cummins Co., Indpls. 7, Ind.
H. J. Somers, Inc., 6063 Wabash Ave., Detroit 8, Mich.
V. E. Sprouse Co., Inc., Columbus, Ind.
Standard Elec. Mfg. Co., W. Berlin, N.J.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., Boston 36, Mass. *(p. 16)*
O. A. Sutton Corp., KFH Bldg., Wichita, Kan.
Swift Mfg. Co., Inc., 1455 E. Nine Mile Rd., Hazel Park, Mich.
Torrington Mfg. Co., 70 Franklin St., Torrington, Ct. *(p. 99)*
Trane Co., La Crosse, Wis. *(p. 12)*
Transaire Mfg. Co., Div. of Penn Elec. Motor Co., 1825 Wylie Ave., Phila. 30, Pa. *(p. 98)*
U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
U. S Thermo Control Co., 44 S. 12th St., Minneapolis 4, Minn.
Utility Appliance Corp., 4851 S. Alameda St., Los Angeles 11, Cal.
Viking Air Conditioning Corp., 5600 Walworth Ave., Cleveland 2, O.
Water Cooling Equip. Corp., Afton Sta., St. Louis 23, Mo.
L. J. Wing Mfg. Co., 154 W. 14th St., N.Y.C. 11

FANS, CONDENSER

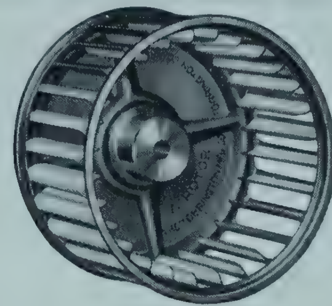
Transaire Mfg. Co., Div. of Penn Elec. Motor Co 1825 Wylie Ave., Phila. 30, Pa. *(p. 9*

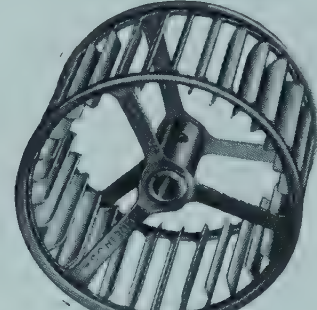
FAN BLADES & FAN PARTS (See also BLOWE WHEELS)

Acme Equip. Co., 205 E. Broadway, Muskogee, Okla.
Aire-Foile Fan & Blower Co., 2909 Central, Detroit Mich.
Airmaster Corp., 4317 Ravenswood Ave., Chicago 13, I
Thomas Beckett & Co., Inc., P.O. Box 7354, Dallas Tex.
C & H Air conditioning Fan Co., Inc., 1603 DeKalb Av N.E., Atlanta, Ga.
Dual-Air Fan Co., P.O. Box 169, S. Elgin, Ill.
General Industries Co., Olive & Taylor St., Elyria, O.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Lehigh Fan & Blower Co., Div. of Heilman Boiler Wk Inc., 128 Linden St., Allentown, Pa.
Martin Fan & Blower Co., 4634 W. 21st Place, Chica 50, Ill.
Maury Mfg. Corp., 2907 S. Wabash Ave., Chicago 16, I
Meier Elec. & Machine, 3525 E. Washington, Indpls. Ind.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 1 Ill.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinn Heating & Ventilating Co., Inc., 1948 N. 9th St., S Louis 6, Mo.
V. E. Sprouse Co., Inc., Columbus, Ind.
Standard Elec. Mfg. Co., W. Berlin, N.J.
Swift Mfg. Co., Inc., 1455 E. Nine Mile Rd., Hazel Par Mich.
Transaire Mfg. Co., Div. of Penn Elec. Motor Co 1825 Wylie Ave., Phila. 30, Pa. *(p. 9*
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
Victor Elec. Products, Inc., 2950 Robertson Rd., Cin'ti. O.
Viking Air Conditioning Corp., 5600 Walworth Av Cleveland 2, O.

FAN COIL UNITS (See AIR CONDITIONING FA COIL UNITS)

Vairified* AIR IMPELLERS

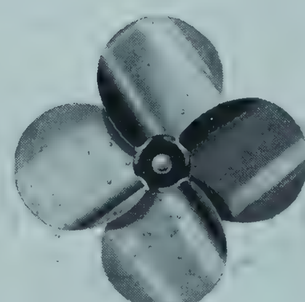




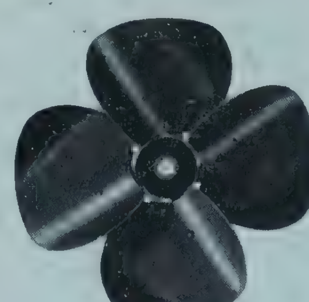
SHOULD BE SELECTED DURING EARLY STAGES OF UNIT DESIGN

By consulting Torrington during the early stages of product design, manufacturers planning the inclusion of an air impeller in a new unit will secure the greatest good from our long experience in the application of forced air.

The annoying, sometimes embarrassing delays and expense of design changes can be avoided with expert help at the right time, which, we repeat, is *in the beginning.*



From among the wide range of sizes, pitches and styles of Airistocrat propeller type fan blades, or sizes and widths of Airotor blower wheels, the correct air impeller for your needs can usually be supplied. Write or phone for information.



*Vairified . . . aerodynamically designed for maximum operating efficiency with quietness; guaranteed to perform as rated under NAFM and NEMA Test Code conditions; hand gauged for uniform contour, alignment and balance. The Torrington Manufacturing Company.

TORRINGTON

MANUFACTURING COMPANY, TORRINGTON, CONN.

FARM FREEZERS (See HOME & FARM FREEZERS)

FASTENERS & FASTENING DEVICES (See also BOLTS, NUTS, SCREWS, etc.)

Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Devices, Inc., 214 E. 53rd St., N.Y.C. 22
Dzus Fastener Co., Inc., Babylon, N.Y.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Lexington Supply Co., 4815 Lexington Ave., Cleveand 3, O.
Miracle Adhesives Corp., 214 E. 53rd St., N.Y.C. 22
Goodloe E. Moore Co., 2811 N. Vermilion, Danville, Ill.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Prestole Corp., 1345 Miami St., Toledo, O.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Shakeproof, Inc., 2501 N. Keller Ave., Chicago 39, Ill.
Simmons Fastener Corp., N. Broadway, Albany 1, N.Y.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Tinnerman Products, Inc., 2038 Fulton Rd., Cleveland 13, O.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.
United-Carr Fastener Corp., 31 Ames St., Cambridge 42, Mass.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20,

FAUCETS, BEER, CARBONATED WATER, etc.

Hudson Products Co., Inc., 440 St. Aubin, Detroit 7, Mich.
Multiplex Faucet Co., 4325 Duncan Ave., St. Louis 10, Mo.
North Penn Co., 72-5th Ave., N.Y.C. 11
Penn Engrg. & Mfg. Corp., 30 S. Main St., Doylestown, Pa.
R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*

FAUCETS, DRINKING WATER (See DRINKING WATER COOLER FITTINGS)

FELT (See also INSULATION)

American Felt Co., Glenville, Ct.
American Hair & Felt Co., 222 N. Bank Dr., Chicago 54, Ill.
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 E. 19th St., N.Y.C. 11

FERMENTATION ROOMS, BAKERY

Fred D. Pfening Co., 1075 W. 5th Ave., Columbus 8, O.
Union Steel Products Co., 448 Pine St., Albion, Mich. *(p. 182)*

FIBRE, VULCANIZED, SHEET; ROD; TUBE, etc.

Anchor Packing Co., 401 N. Broad St., Phila. 8, Pa.
Continental Diamond Fibre Co., 3 Chapel St., Newark, Del.
Taylor Fibre Co., Norristown, Pa.
Technical Ply-Woods, 228 N. La Salle St., Chicago 1, Ill.
Wilmington Fiber Specialty Co., P.O. Drawer 1028, Wilmington 99, Del.
Grant Wilson, Inc., 316 S. La Salle St., Chicago 4, Ill.
Wolverine Fabricating & Mfg. Co., Inc., Princess St. & M.C.R.R., Inkster, Mich.

FILTERS (See particular type; also STRAINERS; also SCALE TRAPS)

FILTERS, AIR (See AIR FILTERS)

FILTERS, AIR LINE

Carborundum Co., P.O. Box 337, Niagara Falls, N.Y.
Chicago Filter Co., Joliet, Ill.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Cuno Engrg. Corp., 92 S. Vine St., Meriden, Ct.
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Electric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
Gas & Oil Industry Labs., Inc., 4 Paine Ave., Irvington 11, N.J.
Logan Engrg. Co., 4801 W. Lawrence, Chicago 30, Ill.
Moore Products Co., H & Lycoming Sts., Phila. 24, Pa.
C. A. Norgren, 222 Santa Fe Drive, Denver, Col.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.

FILTERS, MAGNETIC

Fischer & Porter Co., Hatboro, Pa.
Stearns Magnetic Mfg. Co., 667 S. 28 St., Milwaukee 4, Wis.

FILTERS, OIL

Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
Bowser, Inc., 1302 E. Creighton Ave., Ft. Wayne 2, Ind.
Buffalo Wire Wks., 3200 Terrace, Buffalo 2, N.Y.
Burt Mfg. Co., 932 S. High St., Akron 11, O.
Carborundum Co., P.O. Box 337, Niagara Falls, N.Y.
Cochrane Corp., 17th St., below Allegheny Ave., Phila. 32, Pa.
Cuno Engrg. Corp., 92 S. Vine St., Meriden, Ct.
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Electric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Fischer & Porter Co., Hatboro, Pa.
Fram Corp., 55 Pawtucket Ave., Providence 16, R.I.
Honan-Crane Corp., Div. of Houdaille-Hershey Corp., 64 Indiana Ave., Lebanon, Ind.
McIntire Connector Co., 252 Jefferson St., Newark 5, N.J. *(p. 84)*
Wm. W. Nugent & Co., Inc., 410 N. Hermitage Ave., Chicago 22, Ill.
W.G.B. Oil Clarifier, Inc., Kingston, N.Y.

FILTERS, REFRIGERANT (See also STRAINERS)

Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*
Amplex Div., Chrysler Corp., 6501 Harper Ave., Detroit 31, Mich.

ıtomatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. (p. 96)
ıker Refrigerator Corp., S. Windham, Me. (p. 48)
ıno Engrg. Corp., 92 S. Vine St., Meriden, Ct.
ɛrsch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. (p. 190)
ɔllinger Corp., 1 Centre Park, Rochester 3, N.Y.
ɛnry Valve Co., Melrose Park, Ill. (p. 100)
ıperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. (p. 110)
ɛlvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. (p. 59)
ɛnmore Machine P.oducts, Inc., 15 Depew Ave., Lyons, N.Y.
ɛrotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. (p. 213)
ıcIntire Connector Co., 252 Jefferson St., Newark 5, N.J. (p. 84)
ichigan Wire Cloth Co., 2098 Howard St., Detroit 16, Mich.
oraine Products Div., Gen'l. Motors Corp., Dayton 1, O.
ueller Brass Co., Port Huron, Mich.
efrigerating Specialities Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
emco, Inc., Zelienople, Pa. (p. 107)
uperior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. (p. 106)
ılter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (p. 43)
'abash Mfg. Co., 2300 S. Western Ave., Chicago 8, Ill.

ILTERS, WATER

merican Water Softener Co., S.E. Corner 4th & Lehigh Ave., Phila. 33, Pa.
ello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.
uffalo Wire Works, 3200 Terrace, Buffalo 2, N.Y.
uhring Water Purifying Co., P.O. Box 155, Atlantic Highlands, N.J.
'algon, Inc., Hagan Bldg., Pittsburgh 30, Pa.
'arborundum Co., P.O. Box 337, Niagara Falls, N.Y.
ochrane Corp., 17th St. below Allegheny Ave., Phila. 32, Pa.
uno Engrg. Corp., 92 S. Vine St., Meriden, Ct.
)ollinger Corp., 1 Centre Park, Rochester 3, N.Y.
lectric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
lgin Softener Corp., Elgin, Ill.
'ilter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
'iltrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. (p. 220)
'ischer & Porter Co., Hatboro, Pa.
reer Hydraulics, Inc., 454-18th St., Brooklyn 15, N.Y.
Henry Valve Co., Melrose Park, Ill. (p. 100)
Iugerford & Terry, Inc., 226 Atlantic Ave., Clayton, N.J.
nfilco, Inc., 325 W. 25th St., Chicago 16, Ill.
McIntire Connector Co., 252 Jefferson St., Newark 5, N.J. (p. 84)
Wm. W. Nugent & Co., Inc., 410 N. Hermitage Ave., Chicago 22, Ill.
)shkosh Filter & Softener Co., 51 Ceape St., Oshkosh, Wis.
Puro Filter Corp. of America, 440 Lafayette St., N.Y.C. 3
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Schwartz Mfg. Co., Two Rivers, Wis.
Sunroc Co., Glen Riddle, Pa. (p. 86)
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.

FINISHES

Acme White Lead & Color Wks., 8250 St. Aubin Ave., Detroit, Mich.
American Chemical Paint Co., Ambler, Pa.
American Marietta Co., 43 E. Ohio St., Chicago, Ill.
Arco Co., 7301 Bessemer Ave., Cleveland 4, O.
Atlas Powder Co., N. Chicago, Ill.
Baer Bros., 438 W. 37th St., N.Y.C. 18
Chicago Vitreous Enamel Product Co., 1407 S. 55th Court, Cicero 50, Ill.
Dennis Chemical Co., 2701 Papin St., St. Louis 3, Mo.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
Ernecke & Salmstein Co., 1611 N. Sheffield Ave., Chicago 14, Ill.
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Glidden Co., 11001 Madison Ave., Cleveland 2, O.
Grand Rapids Varnish Corp., 1350 Steele Ave., S.W., Grand Rapids 2, Mich.
Alfred Hague & Co., 227-34th St., Brooklyn 32, N.Y.
Hercules Powder Co., Delaware Trust Bldg., Wilmington, Del.
A. C. Horn Co., Inc., 43-36-10th St., Long Island City, N.Y.
Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N.J.
Interchemical Corp., 57 State St., Newark, N.J.
Jones-Dabney Co., Div. of Devoe & Raynolds, 1481 S. 11th St., Louisville 8, Ky.
Maas & Waldstein Co., 438 Riverside Ave., Newark 4, N.J.
Master Mechanics Co., Freeman Rd., Cleveland 13, O.
Midland Paint & Varnish Co., 3801 E. 91st St., Cleveland 5, O.
Monsanto Chemical Co., 600 Monsanto Ave., Springfield 2, Mass.
National Lead Co., 111 Broadway, N.Y.C. 6
Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O
O'Neil Duro Co., P.O. Box 1166, Milwaukee 1, Wis.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Quigley Co., Inc., 527-5th Ave., N.Y.C. 17
Randolph Products Co., Carlstadt, N.J. (p. 101)
Sherwin-Williams Co., 101 Prospect Ave., N.W., Cleveland, O.
L. Sonneborn Sons, Inc., 88 Lexington Ave., N.Y.C. 16
Steelcote Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo.
United Chromium, Inc., 51 E. 42nd St., N.Y.C. 17
U. S. Gutta Percha Paint Co., Dudley & Eddy Sts., Providence 1, R.I.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J
Zapon Div., Atlas Powder Co., Stamford, Ct.

FINISHES, INSULATION

Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.

(Continued)

FINISHES, INSULATION (Continued)

Eagle-Picher Sales Co, American Bldg., Cin'ti. 1, O.
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Master Mechanics Co., Freeman Rd., Cleveland 13, O.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
United Chromium, Inc., 51 E. 42nd St., N.Y.C. 17
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.

FINNED COILS

(A—Ammonia; B—Other refrigerants)

(A,B) Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
(A,B) Aerofin Corp., 410 Geddes St., Syracuse, N.Y. *(p. 15)*
(B) American Coils Co., 25 Lexington St., Newark 5, N.J.
(A,B) Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Brown Fintube Co., Elyria, O.
(A,B) Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. *(p. 200)*
(A) Cyclops Iron Wks., 837 Folsom St., San Francisco 7, Cal.
(B) Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
(B) Fedders-Quigan Corp., 57 Tonawanda St., Buffalo 7, N.Y. *(p. 53)*
(A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
(B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(B) General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
(A,B) General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. *(p. 58)*
(B) Hastings Air Conditioning Co., Inc., Hastings, Neb.
Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. *(p. 204)*
(B) Hussmann Refrigerator Co., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*

(A,B) Industrial Mfg. & Engrg. Co., 3845 N. Ravenswoo Ave., Chicago 13, Ill.
(A,B) Kennard Corp., 1819 S. Hanley Rd., St. Lou 17, Mo. *(p. 1*
Kramer-Trenton Co., Olden & Breuning Aves Trenton 5, N.J. *(p. 20*
Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, G *(p. 20*
(B) McCord Corp., Riopelle & E. Grand Blvd Detroit 11, Mich. *(p. 3*
(A,B) McQuay, Inc., 1600 Broadway, N.E., Minnea olis 13, Minn. *(p. 20*
(A,B) Marlo Coil Co., 6135 Manchester Ave., St. Lou 10, Mo. *(p. 20*
(B) Melco Mfg. Co., Inc., Grand Ave., Ridgefield, N.J
(A,B) Peerless of America, Inc., 2901 Lawrence Ave., Ch cago 25, Ill.
(B) Reese & Long Refrigeration Products, Inc., 408 25th St., N.Y.C. 10
(A,B) Refrigeration Appliances, Inc., 917 W. Lake S Chicago 7, Ill.
(A,B) Refrigeration Economics Co., Inc., 1231 Tuscarawas St., Canton 4, O. *(p. 20*
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., L Angeles, Cal. *(p. 21*
(A,B) Rempe Co., 340 N. Sacramento Blvd., Chicago 1 Ill.
(B) Rome-Turney Radiator Co., Rome, N.Y. *(p. 3*
(A,B) Stewart Ice Machine Co., 1282 W. 1st St., Pomon Cal.
(B) Super-Cold Corp., 1020 E. 59th St., Los Angeles Cal.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) U. S. Air Conditioning Corp., Como Ave., S.E., 33rd St., Minneapolis 14, Minn.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee Wis. *(p. 4*
(B) Wittenmeier Machinery Co., 850 N. Spaulding Av Chicago 51, Ill.
(A,B) Worthington Pump & Machinery Corp., Ha rison, N.J. *(p. 11*
(A,B) XL Refrigerating Co., 1834 W. 59th St., Chica 36, Ill.
(A,B) York Corp., York, Pa. *(p. 11*
Young Radiator Co., Racine, Wis. *(p.*

FINNED TUBING

Aerofin Corp., 410 Geddes St., Syracuse N.Y. *(p. 1*
American Coils Co., 25 Lexington St., Newark 5, N.J.
Brown Fintube Co. Elyria, O.
Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. *(p. 20*
Carpenter Steel Co., Reading, Pa.
Detroit Ice Machine Co., 2615-12th St., Detroit, Mic
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 3 N.Y. *(p. 5*
G & O Mfg. Co., 138 Winchester Ave., New Haven 8, C
Heintz Mfg. Co., Front St. & Olney Ave., Phila. 20, Pa
Industrial Mfg. & Engrg. Co., 3845 N. Ravenswood Av Chicago 13, Ill.
David E. Kennedy, Inc., 58-2nd Ave., Brooklyn 1 N.Y. *(p. 1*
Kramer-Trenton Co., Olden & Breuning Ave Trenton 5, N.J. *(p. 20*
McCord Corp., Riopelle & E. Grand Blvd., Detr 11, Mich. *(p. 3*
Melco Mfg. Co., Inc., Grand Ave., Ridgefield, N.J.
Refrigeration Economics Co., Inc., 1231 E. Tusc rawas St., Canton 4, O. *(p. 2*
Refrigeration Engrg., Inc., 7250 E. Slauson Ave., L Angeles, Cal. *(p. 21*
Rome-Turney Radiator Co., Rome, N.Y. *(p. 3*
Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
Tilco Fin Div., David E. Kennedy, Inc., 58-2nd Av Brooklyn 15, N.Y. *(p. 1*
Wolverine Tube Div., Calumet & Hecla Cons. Copp Co., 1411 Central Ave., Detroit 9, Mich.
Young Radiator Co., Racine, Wis. *(p.*

FISH REFRIGERATORS (See DISPLAY CASES)

FITTINGS, AMMONIA

Baker Refrigeration Corp., S. Windham, Me. *(p.*
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columb O.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p.*

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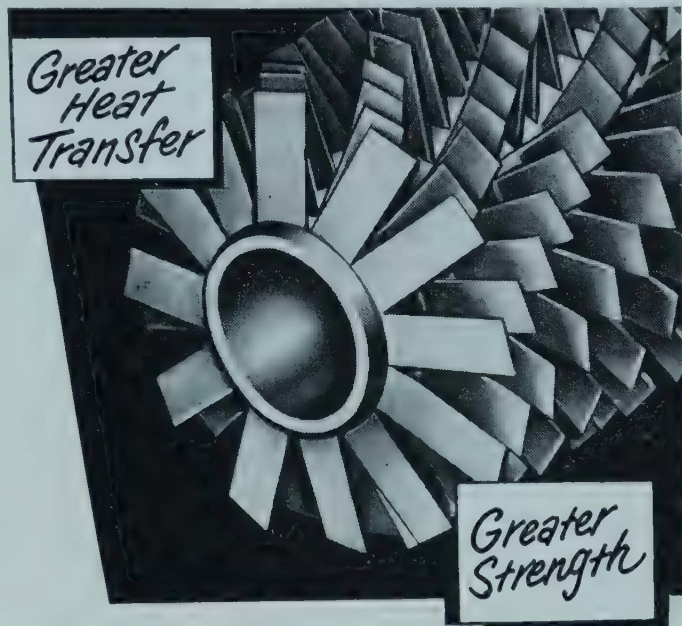

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FITTINGS, AMMONIA (Continued)

Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Frick Co., Waynesboro, Pa. *(p. 44)*
Henry Valve Co., Melrose Park, Ill. *(p. 102)*
Cyrus Shank Co., 625 W. Jackson Blvd., Chicago 6, Ill.
Tube-Turns, Inc., 224 E. Broadway, Louisville 1, Ky.
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119)*

FITTINGS, BRAZING & SOLDERING

Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Grabler Mfg. Co., 6565 Broadway, Cleveland 5, O.
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Charles W. Krieg Co., 48 Dickerson St., Newark 4, N.J.
Mueller Brass Co., Port Huron, Mich.
National Lead Co., 111 Broadway, N.Y.C. 6
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Watson-Stillman Co., Roselle, N.J. *(p. 109)*

FITTINGS, CAPILLARY TUBE

Wabash Mfg. Co., 2300 S. Western Ave., Chicago 18, Ill.

FITTINGS, CARBON DIOXIDE

Capitol Mfg. & Supply Co., 153 W. Fulton St., Columb O.
Frick Co., Waynesboro, Pa. *(p.*
Tube-Turns, Inc., 224 E. Broadway, Louisville 1, Ky.
Vibraseal Corp., 2832 E. Grand Blvd., Detroit 11, Mi
Watson-Stillman Co., Roselle, N.J. *(p. 1*
Wittenmeier Machinery Co., 850 N. Spaulding Ave., C cago 51, Ill.
Worthington Pump & Machinery Corp., Harris N.J. *(p. 1*
York Corp., York, Pa. *(p. 1*

FITTINGS, CAST IRON

American Flexible Coupling Co., 1808 Pittsburgh A Erie, Pa.
James B. Clow & Sons, 201 N. Talman Ave., Chicago Ill.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 1*
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Grabler Mfg. Co., 6565 Broadway, Cleveland 5, O.
Grinnell Co., 260 W. Exchange St., Providence 1, R.I
Jarecki Mfg. Co., 1345 W. 12th St., Erie, Pa.
Kennedy Valve Mfg. Co., Elmira, N.Y.
Henry Vogt Machine Co., 10th & Ormsby St., Louisv 10, Ky.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
J. P. Ward Foundries, Inc., Blossburg, Pa.
Warren Foundry & Pipe Corp., 11 Broadway, N.Y.C.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36,
J. A. Zurn Mfg. Co., Erie, Pa.

FITTINGS, COMPRESSION (See also FITTIN FLARE)

Chase Brass & Copper Co., 236 Grand St., Waterbury Ct.
Commonwealth Brass Corp., 5835 Commonwealth A Detroit 8, Mich.
Consolidated Brass Co., 139 Summit St., Detroit 9, Mi

(Continu

FITTINGS, COMPRESSION (Continued)

Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin'ti 14, O.
Wm. W. Nugent & Co., Inc., 410 N. Hermitage Ave., Chicago 22, Ill.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.

FITTINGS, DUCT (See DUCT ACCESSORIES)

FITTINGS, ELECTRIC CONDUIT (See also CLAMPS, CONDUIT & CABLE)

Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
General Elec. Co., 1285 Boston Ave., Bridgeport 2, Ct.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Minerallac Elec. Co., 25 N. Peoria St., Chicago 7, Ill.
National Elec. Products Corp., Fulton Bldg., Pittsburgh 22, Pa.
Pyle-Nat'l. Co., 1371 W. 37th St., Chicago 9, Ill.

FITTINGS, FLANGED

James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Frick Co., Waynesboro, Pa. *(p. 44)*
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.

Jarecki Mfg. Co., 1345 W. 12th St., Erie, Pa.
Kennedy Valve Mfg. Co., Elmira, N.Y.
Marman Products Co., Inc., 940 Redondo, Inglewood, Cal.
Phoenix Mfg. Co., Joliet, Ill.
Standard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Warren Foundry & Pipe Corp., 11 Broadway, N.Y.C. 4
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa *(p. 119)*

FITTINGS, FLARE INVERTED

Brockway Co., 361 Church St., Naugatuck, Ct.
Commonwealth Brass Corp., 5835 Commonwealth Ave., Detroit 8, Mich.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill
Imperial Brass Mfg. Co., 537 S. Racine Ave. Chicago 7, Ill. *(p. 110)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.

FITTINGS, FLARE, REFRIGERANT

Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Commonwealth Brass Corp., 5835 Commonwealth Ave., Detroit 8, Mich.
Consolidated Brass Co., 139 Summit, Detroit 9, Mich.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill
Imperial Brass Mfg. Co., 437 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22 Pa. *(p. 218)*
Madden Brass Products Co., 111 N. Franklin St., Chicago 10, Ill.
Mueller Brass Co., Port Huron, Mich.
Remco, Inc., Zelienople, Pa. *(p. 107)*
Scoville Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 106)*
Uniflex Metal Hose Co., 52 Rubber Ave., Naugatuck, Ct
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.

FITTINGS, FORGED

Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
Catawissa Valve & Fittings Co., 206 Main St., Catawissa, Pa.
Commonwealth Brass Corp., 5835 Commonwealth Ave., Detroit 8, Mich.
Consolidated Brass Co., 139 Summit, Detroit 9, Mich.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago 1, Ind.
Henry Valve Co., Melrose Park, Ill. *(p. 10-)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Phoenix Mfg. Co., Joliet, Ill.
Taylor Forge & Pipe Wks., P.O. Box 485, Chicago 90, Ill
Tube-Turns, Inc., 224 E. Broadway, Louisville 1, Ky.
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill
York Corp., York, Pa. *(p. 119)*

FITTINGS, HARD RUBBER

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5 N.Y.

(Continued)

FITTINGS, HARD RUBBER (Continued)

Luzerne Rubber Co., Trenton 9, N.J.
National Motor Bearing Co., Inc., Redwood City, Cal.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J.
Thermoid Co., Trenton, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

FITTINGS, HOSE (See also HOSE CLAMPS)

Aeroquip Corp., 300 S. East Ave., Jackson, Mich.
Aircraft Standard Parts Co., Inc., 1711-19th Ave., Rockford, Ill.
Anchor Packing Co., 401 N. Broad St., Phila. 8, Pa.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
DeVilbiss Co., 300 Phillips Ave., Toledo 1, O.
Flexible Tubing Corp., N. Main St., Branford, Ct.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Marman Products Co., Inc., 940 Redondo, Inglewood Cal.
C. A. Norgren, 222 Santa Fe Drive, Denver, Col.
Thermoid Co., Trenton, N.J.
Tinnerman Products, Inc., 2038 Fulton Rd., Cleveland 31, O.
John M. Watt's Sons, 112 Walnut St., Phila., Pa.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.

FITTINGS, PIPE

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Brockway Co., 361 Church St., Naugatuck, Ct.
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Commonwealth Brass Corp., 5835 Commonwealth Ave., Detroit 8, Mich. (Brass only)
Cooper Alloy Foundry Co., Bloy St. & Ramsey Ave., Hillside 5, N.J.
Crane Co., 836 Michigan Ave., Chicago 5, Ill *(p. 105)*
E. M. Dart Mfg. Co., 134 Thurbers Ave., Providence 5, R.I.
Defiance Automatic Screw Co., Ft. Wayne Rd., Defiance, O.
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Dresser Mfg. Div., Dresser Industries, Inc., 490 Fisher Ave., Bradford, Pa.
Duriron Co., Inc., Dayton 1, O.
Ellsworth Pipe & Supply Co., 513 W. Traser St., Milwaukee 3, Wis.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Fairbanks Co., 393 Lafayette, N.Y.C. 3
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Frick Co., Waynesboro, Pa. *(p. 44)*
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
Grabler Mfg. Co., 6565 Broadway, Cleveland 5, O.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Haynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
Henry Valve Co., Melrose Park, Ill. *(p. 102)*
Holo-Krome Screw Corp., 25 Brook St., Hartford 10, Ct.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Jarecki Mfg. Co., 1345 W. 12th St., Erie, Pa.
Jefferson Union Co., Inc., 71 Gooding St., Lockport, N.Y.
Kennedy Valve Mfg. Co., Elmira, N.Y.
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Charles W. Krieg Co., 48 Dickerson St., Newark 4, N.J.
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin'ti. 14, O.
Marman Products Co., Inc., 940 Redondo, Inglewood, Cal.
Minerallac Elec. Co., 25 N. Peoria St., Chicago 7, Ill.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Carbon Co., Inc., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
M. B. Skinner & Co., South Bend 23, Ind. *(p. 104)*
Taylor Forge & Pipe Wks., P.O. Box 485, Chicago 90, Ill.
Tube-Turns, Inc., 224 E. Broadway, Louisville 1, Ky.
Uniflex Metal Hose Co., 52 Rubber Ave., Naugatuck, Ct.
Victaulic Co. of America, 30 Rockefeller Plaza, N Y.C. 20
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
J. P. Ward Foundries, Inc., Blossburg, Pa.
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill
York Corp., York, Pa. *(p. 119)*
J. A. Zurn Mfg. Co., Erie, Pa.

FITTINGS, SHEET METAL (See DUCT ACCESSORIES; also DUCTWORK, PREFABRICATED)

FITTINGS, WELDING

Bonney Forge & Tool Wks., Allentown, Pa.
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
Catawissa Valve & Fittings Co., 206 Main St., Catawissa, Pa.
Cooper Alloy Foundry Co., Bloy St. & Ramsey Ave., Hillside 5, N.J.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Frick Co., Waynesboro, Pa. *(p. 44)*
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Haynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Taylor Forge & Pipe Wks, P.O. Box 485, Chicago 90, Ill.
Tube-Turns, Inc., 224 E. Broadway, Louisville 1, Ky.
Vilter Mfg. Co., 2223 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Watson-Stillman Co., Roselle, N.J. *(p. 109)*

FLAKE ICE MACHINERY (See ICE MAKING MACHINES)

FLANGE ADAPTERS (See ADAPTER FLANGES)

FLANGES, PIPE (See FITTINGS)

FLEXIBLE CONNECTIONS (See also CHARGING LINES; also TUBING, FLEXIBLE; also SWING JOINTS; also VIBRATION ABSORBERS, LINE)

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Chicago Metal Hose Corp., Maywood, Ill.
Eclipse Aviation Metal Hose Dept., Div. of Bendix Aviation Corp., Phila. 44, Pa.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Flexible Tubing Corp., N. Main St., Branford, Ct.
Henry Valve Co., Melrose Park, Ill. *(p. 102)*
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Johnson Metal Hose Co., 226 Mill St., Waterbury 88, Ct.
Marman Products Co., Inc., 940 Redondo, Inglewood, Cal.
Resistoflex Corp., 39 Plansoen St., Belleville 9, N.J.
Seamlex Co., Inc., 4123-24th St., Long Island City 1, N.Y.
Uniflex Metal Hose Co., 52 Rubber Ave., Naugatuck, Ct.
York Corp., York, Pa. *(p. 119)*

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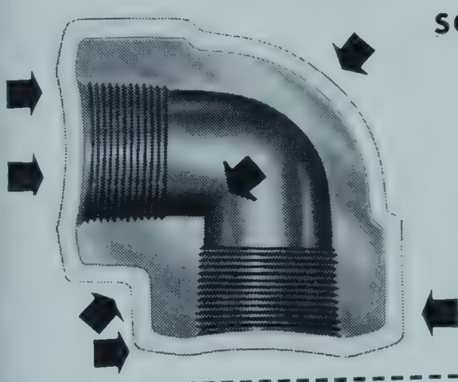

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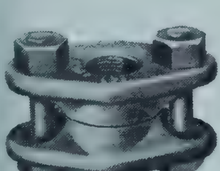

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Screw and Socket Weld Types.

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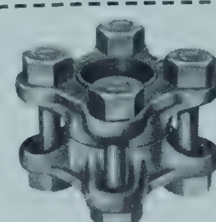
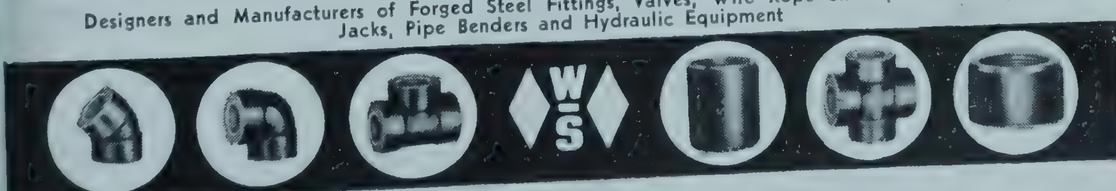


DISTRIBUTOR PRODUCTS DIV. **WATSON-STILLMAN** ROSELLE, NEW JERSEY

Designers and Manufacturers of Forged Steel Fittings, Valves, Wire Rope Shears, Hand Pumps, Jacks, Pipe Benders and Hydraulic Equipment

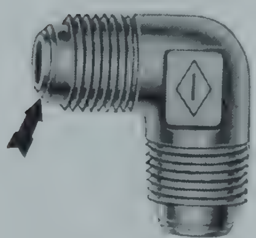


The Imperial Brass Mfg. Company

537 So. Racine Ave., Chicago 7, Ill.

Fittings • Valves • Driers • Filters • Floats • Charging Line
Tools for: Cutting • Flaring • Bending • Pinch-off • Swedgin

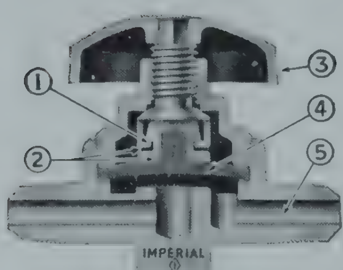
TRIPLE-SEAL FLARED TUBE FITTINGS



Imperial Fittings give extra protection against leakage becaus a groove in the seat of sizes ⅜″ and larger provides a self-seatin joint that will remain leak-proof even though the face of the sea may be nicked or marred.

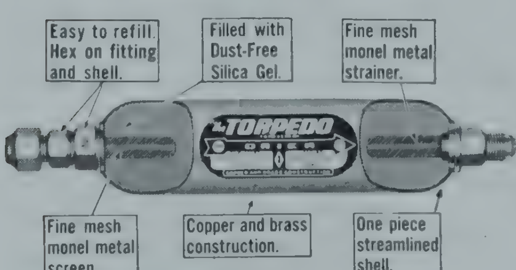
Nuts, tees and elbows are made from brass forgings. This assure a fine grain structure, freedom from internal stress, high tensil strength and the elimination of seepage, season cracking or splittin Elbows and tees have flats for wrench grip. Extra length pip threads.

DIASEAL VALVE



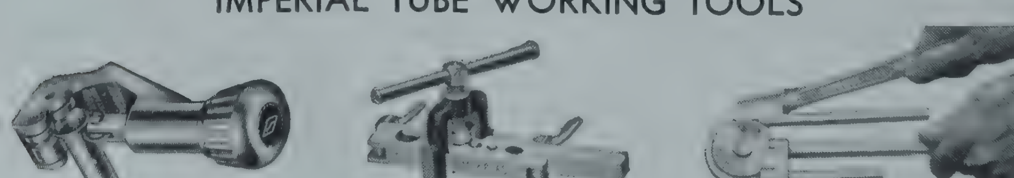
A better, more dependable diaphragm valve for refrigeration an air conditioning use. Offers many outstanding advantages: (1) N Springs—direct lift provides positive control with flow in eithe direction. (2) Only Two Moving Parts—simple construction as sures greater dependability. (3) Easy Finger-Tip Action—quick sure opening and closing with less than two turns of handle. (4 Long Life Diaphragm is impervious to all common refrigerants Has withstood over 1,000,000 openings and closings in tests unde refrigerant pressure. (5) Inlet and Outlet Ports in line. Simplifie installation.

TORPEDO DRIER



Designed for greater efficiency and faster dry ing action. Note these features: (1) One piec streamlined copper shell which provides greate strength, lighter weight, fewer joints and les chance for leakage; (2) charged with ne Dust-Free Silica Gel; (3) ample filtering are provided on all sizes, graduated with size c drier; (4) interchangeable tubing connectio on larger sizes; (5) easy to refill.

IMPERIAL TUBE WORKING TOOLS



Good tools are essential to making first class tubing connections. Imperial tube working tools have proven their quality and ease of operation.

The line includes tube cutters, flaring tools, tube benders, reamers, and swedging tools for working with copper, brass, aluminum and thin-wall steel tubing.

Illustrated above are 274-F Tube Cutter f ⅛″ to 1″ O.D. tubing; 195-F Flaring Tool f ¼″ to ⅝″ O.D. Tubing; and 364-F Tube Bend for ⅛″ to ¾″ O.D. Tubing. (Individual bend for each size.) Many others also available.

EXIBLE COUPLINGS (See also SHAFT COUPLINGS)

ldwin Duckworth Div., Chain Belt. Co., 369 Plainfield St., Springfield, Mass.
pitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
ntric Clutch Co., 23 South Ave., W. Cranford, N.J.
ngress Drive Div., Tann Corp., 3750 E. Outer Drive, Detroit 34, Mich.
frey Mfg. Co., 887 N. 4th St., Columbus 16, O.
A. Jones Foundry & Machine Co., 4401 Roosevelt Rd., Chicago 24, Ill.
nk-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind. (Shaft)
rd Mfg. Co., 1635 W. 12th St., Erie, Pa. (For power Transmission)
arman Products Co., Inc., 940 Redondo, Inglewood, Cal.
H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
iladelphia Gear Wks., Inc., G St. & Erie Ave., Phila. 20, Pa.
msey Chain Co., Inc., 900 Broadway, Albany 1, N.Y.
niflex Metal Hose Co., 52 Rubber Ave., Naugatuck, Ct.
ater Cooling Corp., 71 Nassau St., N.Y.C. 7 (Pipe)

OAT BALLS

cklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*
hicago Float Wks., Inc., 2330 S. Western Ave., Chicago 8, Ill.
onsolidated Brass Co., 139 Summit, Detroit 9, Mich.
nst Water Column & Gage Co., 250 S. Livingston Ave., Livingston, N.J.
rthur Harris & Co., 210 N. Aberdeen St., Chicago 7, Ill.
ndustrial Wire Cloth Products Corp., Wayne, Mich. *(p. 85)*
lipfel Valves, Inc., 1000 Weller Ave., Hamilton, O.
. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa
okes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber)

LOATS, LIQUID LEVEL CONTROL (See FLOAT SWITCHES; also HIGHSIDE FLOATS; also LOWSIDE FLOATS; also CONTROLS, LIQUID LEVEL)

LOAT SWITCHES (See also HIGHSIDE FLOATS; also LOWSIDE FLOATS)

lco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
llen-Bradley Co., Milwaukee 4, Wis.
utomatic Control Co., 1005 University Ave., St. Paul 4, Minn.
ischer & Porter Co., Hatboro, Pa. (Flow Alarm)
Frick Co., Waynesboro, Pa. *(p. 44)*
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hancock Valve Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
McDonnell & Miller, Inc., 1316 Wrigley Bldg., Chicago 11, Ill.
Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Soreng Mfg. Corp., 9555 Eden Ave., Schiller Park, Ill.

FLOAT VALVES, REFRIGERANT (See HIGHSIDE FLOATS; also LOWSIDE FLOATS)

FLOAT VALVES, WATER

Thomas Beckett & Co., Inc., 2118 Griffin St., Dallas 2, Tex.
Climax Engrg. Co., Controls Div., 15 N. Cincinnati, Tulsa, Okla.
Davis Regulator Co., 2511 S. Washtenaw Ave., Chicago 8, Ill.
Farm Appliances, Inc., Sturgeon Bay, Wis.
Flint & Walling Mfg. Co., Inc., 95 Oak St., Kendallville, Ind.
Klipfel Valves, Inc., 1000 Weller Ave., Hamilton, O.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
McDonnell & Miller, Inc., 1316 Wrigley Bldg., Chicago 11, Ill.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
Robert Mfg. Co., 3417 Crenshaw Blvd., Los Angeles 16, Cal.
Schade Valve Mfg. Co., 2527 N. Bodine St., Phila. 33, Pa.
Trane Co., La Crosse, Wis. *(p. 12)*
Viking Air Conditioning Corp., 5600 Walworth Ave., Cleveland 2, O.

FLORISTS REFRIGERATORS (See REFRIGERATORS, FLORISTS)

FLOW CONTROLS (See REGULATOR, FLOW)

FLOW RATE INDICATORS

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Builders-Providence, Inc., P.O. Box 1342, Providence 1, R.I.
Fischer & Porter Co., Hatboro, Pa.
Gas & Oil Industry Labs., Inc., 4 Paine Ave., Irvington 11 N.J.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I
Hastings Instrument Co., Inc., Hampton, Va.
Hays Corp., Michigan City, Ind.
Henszey Co., 202½ N. Water St., Watertown, Wis.
Infilco, Inc., 325 W. 25th St., Chicago 16, Ill.
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Wm. W. Nugent & Co., Inc., 410 N. Hermitage Ave., Chicago 22, Ill.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.

FLUX, BRAZING, SOLDERING, WELDING, etc.

All-State Welding Alloys Co., Inc., 273 Ferris Ave., White Plains, N.Y.
American Chemical Paint Co., Ambler, Pa.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Handy & Harman, 82 Fulton St., N.Y.C. 7
Charles W. Krieg Co., 48 Dickerson St., Newark 4, N.J.
Lake Chemical Co., 3052 W. Carroll Ave., Chicago 12, Ill.
National Lead Co., 111 Broadway, N.Y.C. 6
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Phila. 7, Pa. (Aluminum)
Ruby Chemical Co., 68 McDowell St., Columbus 8, O.
Tinit Mfg. Co., Inc., 1635 Platte St., Denver 2, Col.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

FLYWHEELS

Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Linderme Machine & Tool Co., 12241 Coyle Ave., Detroit 27, Mich.
Metal Specialty Co., Este Ave. & B&O R.R., Cin'ti., O.

FOAM RUBBER (See RUBBER PRODUCTS, CELLULAR)

FOIL, METALLIC

Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17 *(p. 135)*
Aluminum Co. of America, Pittsburgh 19, Pa.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Johnston Tin Foil & Metal Co., 6106 S. Broadway, St. Louis 11, Mo.
Permanente Products Co., 1924 Broadway, Oakland 12, Cal.
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.

FOOT VALVES (See VALVES, FOOT)

FORECOOLERS (See WATER COOLERS)

FORGINGS

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Aluminum Co. of America, Pittsburgh 19, Pa.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Atlas Drop Forge Co., 209 W. Mt. Hope Ave., Lansing 2, Mich.
Bethlehem Steel Co., Bethlehem, Pa.
Bonney Forge & Tool Wks., Allentown, Pa.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Columbus Bolt Wks. Co., 291 Marconi Blvd., Columbus 16, O.
Kropp Forge Co., 5301 W. Roosevelt Rd., Chicago 50, Ill.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
McInness Steel Co., Corry, Pa.
Mueller Brass Co., Port Huron, Mich. (Aluminum)
New Departure Div., Gen'l. Motors Corp., Bristol, Ct.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.
Phoenix Mfg. Co., Joliet, Ill.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Titan Metal Mfg. Co., Bellefonte, Pa.
Transue & Williams Steel Forging Corp., Alliance, O.
Tube-Turns, Inc., 224 E. Broadway, Louisville 1, Ky.
J. H. Williams & Co., 400 Vulcan St., Buffalo 7, N.Y.
Wyman-Gordon Co., 105 Madison St., Worcester 1, Mass.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119)*

FOUL GAS EXTRACTORS (See PURGERS)

FRAMES, DISPLAY CASE, etc. (See DISPLAY CASE DOORS)

FREEZERS, BATCH, BLAST, CONTINUOUS, QUICK, SHARP, TUNNEL, etc.

Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Belt-Ice Corp., 2845-16th Ave., W., Seattle 99, Wash.
Burge Ice Machine Co., 218 N. Jefferson St., Chicago 6, Ill.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Frick Co., Waynesboro, Pa. *(p. 44)*
King Co., 902 N. Cedar St., Owatonna, Minn.
Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal
U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Votator Div., Girdler Corp., Louisville 1, Ky.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119)*

FREEZER DOORS (See COLD STORAGE DOORS)

FREON REFRIGERANTS

Ansul Chemical Co., Marinette, Wis. (Sales Agents) *(p. 167)*
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del. (Sales Agents)
Eston Chemicals, Inc., 3100 E. 26th St., Los Angeles 23, Cal. (Sales Agents)
Kinetic Chemicals, Inc., 10th & Market Sts., Wilmington, Del. *(p. 113)*
Virginia Smelting Co., W. Norfolk, Va. (Sales Agents) *(p. 168)*

FREQUENCY CHANGERS

Forbes & Myers, 173 Union St., Worcester, Mass.

FRICTION TAPE

H. N. Cook Belting Co., 401 Howard St., San Francis 5, Cal.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 12*
New York Belting & Packing Co., 1 Market St., Passai N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C.
Van Cleef Bros., Inc, 7800 S. Woodlawn Ave., Chica 19, Ill.

FROZEN FOOD CABINETS (See HOME & FAR FREEZERS; also DISPLAY CASES, FROZE FOODS)

FUSES

Bussmann Mfg. Co., University & Jefferson Sts., St. Lou 7, Mo.
Chase-Shawmut Co., Newburyport, Mass.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Jefferson Elec. Co., 25 Ave. & Madison St., Bellwood, I
Littlefuse, Inc., 4757 Ravenswood Ave., Chicago 40, I

FUSIBLE PLUGS

Consolidated Brass Co., 139 Summit, Detroit 9, Mich.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chica 7, Ill. *(p. 11*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 2 Pa. *(p. 21*
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin' 14, O.
Mueller Brass Co., Port Huron, Mich.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N
Superior Valve & Fittings Co., 1509 W. Liberty Av Pittsburgh 26, Pa. *(p. 1*
Swift Lubricator Co., Inc., 101 Home St., Elmira, N.Y
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.

GALVANIZING

W. Ames & Co., Jersey City, N.J.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
L. O. Koven & Bro., Inc., 154 Ogden Ave., Jersey City N.J.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.

GAS COOLERS

Richard M. Armstrong Co., Box 188, W. Chester, *(p.*
Baker Refrigeration Corp., S. Windham, Me. *(p.*
Standard Heater & Oil Equip. Co., 245 Cornelison Av Jersey City 2, N.J.
Worthington Pump & Machinery Corp., Harris N.J. *(p. 1*

GAS MASKS

Acme Protection & Equip. Co., 3616 Liberty Ave., Pi burgh, Pa.
Central Safety Equip. Co., 2200 E. Huntingdon St., Ph 25, Pa.
Chicago Eye Shield Co., 2300 Warren Blvd., Chicago Ill.
Davis Emergency Equip. Co., Inc., 45 Halleck St., N ark 4, N.J.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Mine Safety Appliances Co., Braddock, Thomas & Me Sts., Pittsburgh, Pa.
Pulmosan Safety Equip. Corp., 176 Johnson St., Bro lyn 1, N.Y.
York Corp., York, Pa. *(p. 1*

GASES, RARE

Linde Air Products Co., Unit of Union Carbide & Car Corp., 30 E. 42nd St., N.Y.C. 17
Matheson Co., Inc., P.O. Box 85, E. Rutherford, N.J

GASKET, DOOR (See DOOR GASKET)

Check these

OUTSTANDING FEATURES OF

"FREON"*

SAFE REFRIGERANTS

1 Freedom from moisture . . . not more than 10 parts per million in "Freon-12."
2 Narrow boiling point range . . . confined within limits of 1°C.
3 Not more than 2% non-condensible gases in vapor phase.
4 Freedom from acids. There are none in "Freon."
5 Freedom from high and low boiling products.
6 Nontoxic . . . nonflammable . . . nonexplosive.

Regardless of the temperature required, or the design of the equipment used, there is a "Freon" safe refrigerant that will do the job.

"FREON-11"—CCl_3F—B.P. 74.7°F. (23.7° C.)—For commercial and industrial air conditioning systems employing centrifugal-type compressors.

"FREON-12" — CCl_2F_2 — B.P. -21.6°F. (-29.8°C.)—The most widely used of all "Freon" refrigerants. Used in industrial and commercial air conditioning and household refrigerating systems employing rotary or reciprocating-type compressors, and in industrial and commercial low-temperature refrigerating systems employing centrifugal-type compressors.

"FREON-21" — $CHCl_2F$—B.P. 48.0°F. (8.9°C.)—For industrial and commercial air conditioning systems employing centrifugal-type compressors. Also in fractional horsepower refrigerating systems employing rotary-type compressors and in air conditioning systems of the absorption type.

"FREON-22"—$CHClF_2$—B.P.-41.4°F. (-40.8°C.)—Due to its low boiling point, "Freon-22" is ideal for jobs where low temperatures are necessary. May be used in reciprocating or centrifugal-type compressors.

"FREON-113" — CCl_2F-$CClF_2$ — B.P. 117.6° F. (47.6°C.) — Used in air conditioning systems employing centrifugal-type compressors. Not for low-temperature refrigeration.

"FREON-114" — $CClF_2CClF_2$— B.P. 38.4°F. (3.5°C.)—Used as a refrigerant in household systems employing rotary-type compressors. Also in industrial and commercial low-temperature refrigerating systems employing centrifugal-type compressors.

Full details on "Freon" refrigerants are available from Kinetic Chemicals, Inc., Tenth and Market Sts., Wilmington 98, Delaware.

KINETIC REG. U. S. PAT. OFF.

FREON REG. U. S. PAT. OFF.

"Freon" is Kinetic's registered trade-mark for it's fluorinated hydrocarbon refrigerants.

GASKETS & GASKET MATERIAL

Anchor Packing Co., 401 N Broad St., Phila. 8, Pa.
Armstrong Cork Co., Lancaster, Pa. *(p. 131)*
Belmont Packing & Rubber Co., Butler & Sepviva Sts., Phila. 7, Pa.
Booth Felt Co., 455 19th St., Brooklyn, N.Y.
Chamberlin Co. of America, 1254 LaBrosse St., Detroit 26, Mich.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago-Wilcox Mfg. Co., 7701 Avalon Ave., Chicago 19, Ill.
James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Continental Diamond Fibre Co., 3 Chapel St., Newark, Del.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Darcoid Co., Inc., 145-6th Ave., N.Y.C. 13
Detroit Gasket & Mfg. Co., 12640 Burt Rd., Detroit 23, Mich.
Durabla Mfg. Co., 114 Liberty St., N.Y.C. 6
Endura Mfg. Corp., 45 N. 4th St., Quakertown, Pa.
Ernst Water Column & Gage Co., 250 S. Livingston Ave., Livingston, N.J.
Excelsior Leather Washer Mfg. Co., Inc., Rockford, Ill. (Leather)
Felters Co., 210 South St., Boston 11, Mass.
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Flexitallic Gasket Co., 8th & Bailey Sts., Camden 2, N.J.
Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
Goetze Branch, Johns-Manville Products Corp., Allen Ave., New Brunswick, N.J.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Inland Mfg. Div., Gen'l. Motors Corp., Dayton 1, O.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Keasbey & Mattison Co., Ambler, Pa.
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
McCord Corp., Riopelle & E. Grand Blvd., Detroit 11, Mich. *(p. 37)*
Melrath Supply & Gasket Co., Inc., Tioga & Memphis Sts., Phila. 34, Pa.
Metallo Gasket Co., 10 Bethany St., New Brunswick, N.J.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Resistoflex Corp., 39 Plansoen St., Belleville 9, N.J.
Rhopac, Inc., 168 N. Clinton St., Chicago 6, Ill.
Smooth-On Mfg. Co., 572 Communipaw Ave., Jersey City 4, N.J.
Sponge Rubber Products Co., Howe Ave., Shelton, Ct.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Victor Mfg. & Gasket Co., 5750 Roosevelt Rd., Chicago 90, Ill.
Wilmington Fiber Specialty Co., P.O. Drawer 1028, Wilmington 99, Del.
Wolverine Fabricating & Mfg. Co., Inc., Princess St. & M.C.R.R., Inkster, Mich.
York Corp., York, Pa. *(p. 119)*

GAUGE GLASSES

Semon Bache & Co., 636 Greenwich St., N.Y.C. 14
L. J. Bordo Co., Inc., 115 New St., Glenside, Pa.
Consolidated Brass Co., 139 Summit, Detroit 9, Mich.
Corning Glass Wks., Corning, N.Y.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
Ernst Water Column & Gage Co., 250 S. Livingston Av Livingston, N.J.
Fischer & Porter Co., Hatboro, Pa.
Claude S. Gordon Co., 3000 S. Wallace St., Chicago 1 Ill.
Meade Goodloe, 2133 Beechwood Drive, Los Angeles 2 Cal.
Henry Valve Co., Melrose Park, Ill. *(p. 10*
Paul B. Huyette Co., Inc., 401 N. Broad St., Phila. 8, P
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
J. E. Lonergan Co., 2nd & Race Sts., Phila. 6, Pa.
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin' 14, O.
Nathan Mfg. Co., 416 E. 106th St., N.Y.C. 29
Oil Rite Corp., 3466 S. 13th St., Milwaukee 7, Wis.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pitt burgh 22, Pa.
Sandee Mfg. Co., 5050 W. Foster Ave., Chicago 30, Ill
Sarco Co., Inc., 350 Fifth Ave., N.Y.C. 1 *(p. 17*
Shomatic Div., Hartford Machine Screw Co., P.O. B 1440, Hartford 2, Ct.
Swift Lubricator Co., Inc., 101 Home St., Elmira, N.
Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburg 12, Pa.
Wright-Austin Co., 315 W. Woodbridge St., Detroit 2 Mich.

GAUGE PULSATION ABSORBERS

Ashton Valve Co., 161-1st St., Cambridge 42, Mass.
J. E. Lonergan Co., 2nd & Race Sts., Phila. 6, Pa.
Meriam Instrument Co., 10920 Madison Ave., Clevelar 2, O.
Mueller Brass Co., Port Huron, Mich.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.
U. S. Gauge, Div. of American Machine & Metals, Seller ville, Pa.

GAUGES, AIR FILTER

Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Claude S. Gordon Co., 3000 S. Wallace St., Chicago 1 Ill.
Hays Corp., Michigan City, Ind.
Owens-Corning Fiberglas Corp., 2012 Nicholas Bldg Toledo 1, O. *(p. 2*
U. S. Gauge, Div. of American Machine & Metals, Seller ville, Pa.

GAUGES, ALARM

Ashcroft Gauge Div., Manning, Maxwell & Moore, In Bridgeport 2, Ct.
Ashton Valve Co., 161-1st St., Cambridge 42, Mass.
Automatic Temperature Control Co., Inc., 5212 Pulas Ave., Phila. 44, Pa.
Brown Instrument Co., Div., Minneapolis-Honeyw Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Fischer & Porter Co., Hatboro, Pa.
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23,
Manning, Maxwell & Moore, Inc., Stratford, Ct.
Marshalltown Mfg. Co., Marshalltown, Ia.
Precision Thermometer & Instrument Co., 1442 Brand wine St., Phila. 30, Pa.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.
U. S. Gauge, Div. of American Machine & Metals, Selle ville, Pa.

GAUGES, AMMONIA, COMPOUND, FREO PRESSURE, VACUUM, etc.

Ashcroft Gauge Div., Manning, Maxwell & Moore, In Bridgeport 2, Ct.
Ashton Valve Co., 161-1st St., Cambridge 42, Mass.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O
Boston Auto Gauge Co., 70 West St., Pittsfield, Mass
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeyw Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 1*
Defender Instrument & Regulator Co., 815 Clark Ave., Louis 2, Mo.
DeVilbiss Co., 300 Phillips Ave., Toledo 1, O.
Ernst Water Column & Gage Co., 250 S. Livingston A Livingston, N.J.
Gotham Instrument Co., Inc., 149 Wooster St., N.Y.C
Hays Corp., Michigan City, Ind.

bbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
perial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
guson Gage & Valve, 87 Fellsway, Somerville, Mass.
ingerit, Inc., 16 Hudson St., N.Y.C. 13
E. Lonergan Co., 2nd & Race Sts., Phila. 6, Pa.
nes P. Marsh Corp., Skokie, Ill.
rshalltown Mfg. Co., Marshalltown, Ia.
riam Instrument Co., 10920 Madison Ave., Cleveland 2, O.
rnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
ecision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
chester Mfg. Co., Inc., 100 Rockwood St., Rochester 10, N.Y.
ylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
eksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12

AUGES, DIFFERENTIAL

nerican Meter Co., Inc., 60 E. 42nd St., N.Y.C. 17
iley Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
own Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
ilders-Providence, Inc., P.O. Box 1342, Providence 1, R.I.
efender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
istillation Products, Inc., 755 Ridge Rd., W., Rochester 13, N.Y.
clipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
ays Corp., Michigan City, Ind.
Ieriam Instrument Co., 10920 Madison Ave., Cleveland 2, O.
aylor Instrument Cos , 95 Ames St., Rochester 1, N.Y.
. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
acuum Equip. Div., Distillation Products, Inc., 755 Ridge Rd., W., Rochester 13, N.Y.

AUGES, DRAFT, DUCT PRESSURE, etc.

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
F. W. Dwyer Mfg. Co., 315 S. Western Ave., Chicago 12, Ill.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Hastings Instrument Co., Hampton, Va.
Hays Corp., Michigan City, Ind.
E. Vernon Hill, 6826 W. Highland Ave., Chicago 31, Ill.
Meriam Instrument Co., 10920 Madison Ave , Cleveland 2, O.
Moeller Instrument Co., Inc., 132nd St. & 89th Ave., Richmond Hill 18, N.Y.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd. Detroit 16, Mich.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.

GAUGES, FLOW RATE (See FLOW RATE INDICATORS)

GAUGES, LIQUID LEVEL, TANK, etc. (See also GAUGE GLASSES)

AC Spark Plug Div., Gen'l. Motors Corp., Flint 2 Mich.
Alloy Steel Products Co., Inc., 1508 W. Elizabeth Ave., Linden, N.J. (Stainless Steel)
Ashton Valve Co., 161-1st St., Cambridge 42, Mass.
Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bijur Lubricating Corp., 43-01-22nd St., Long Island City 1, N.Y.
L. J. Bordo Co., Inc., 115 New St., Glenside, Pa.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Builders-Providence, Inc., P.O. Box 1342, Providence 1, R.I.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Consolidated Brass Co., 139 Summit, Detroit 9, Mich.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Ernst Water Column & Gage Co., 250 S. Livingston Ave. Livingston, N.J.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
Hays Corp. Michigan City, Ind.
Henry Valve Co., Melrose Park, Ill. *(p. 115)*
Paul B. Huyette Co., Inc., 401 N. Broad St., Phila. 8, Pa.
Jerguson Gage & Valve, 87 Fellsway, Somerville, Mass.
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
Krueger Sentry Gauge Co., 1056 W. Mason St., Green Bay, Wis.
Liquidepth Indicators, Inc., 42-26-28th St., Long Island City 1, N Y.
Liquidometer Corp., 41-03-36th St., Long Island City 1, N.Y.
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin'ti 14, O.
Nathan Mfg. Co., 416 E. 106th St., N.Y.C. 29
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Rochester Mfg. Co., Inc., 100 Rockwood St., Rochester 10, N.Y.
Swift Lubricator Co., Inc., 101 Home St., Elmira, N.Y.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Wright-Austin Co., 315 W. Woodbridge St., Detroit 26, Mich.
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.

Worthington Pump and Machinery Corp.

Air Conditioning and Refrigeration Division

General Offices: Harrison, N.J.

District Offices and Representatives in Principal Cities

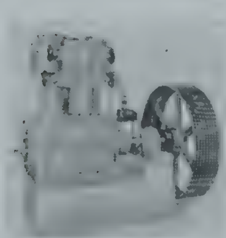
WORTHINGTON

A9-

Refrigeration Systems for Air Conditioning Industrial Process and All Other Applications

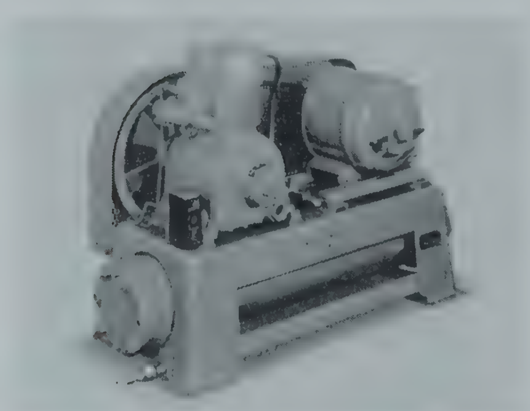
Complete refrigerating systems for use with Freon-11, Freon-12, Methyl Chloride, Ammonia or Ca bon Dioxide, either direct expansion or water cooling applications. A complete line of refrigerati compressors, permitting impartial recommendations. A nation-wide organization of distributors major cities to provide sales and engineering service and to plan complete air conditioning syster of the central or unit type. Architects, Engineers and contractors are invited to consult with Write to Harrison, N.J., or to anyone of our district offices for information on these products.

VERTICAL AMMONIA COMPRESSORS



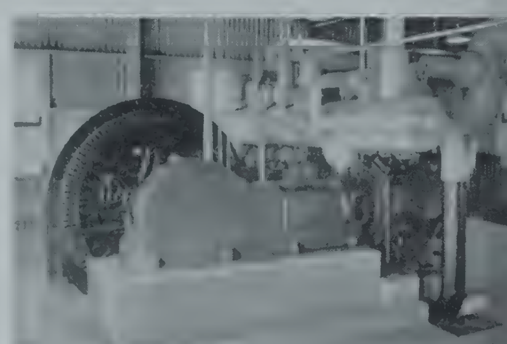
Pressure-lubricated, roller main bearings; safety heads; patented Feather Valves; belt drive or direct connected to electric motor, diesel or gas engine; sizes 3 x 3 to 10 x 10, 2-cylinder.

SELF-CONTAINED FREON-12 CONDENSING UNITS



Capacities from 3 to 100 tons. Condensers are highly efficient multi-pass shell and straight tube type. Condenser heads readily removable, making tubes easily accessible for cleaning. Small sizes have condensers mounted in base; larger units have condenser mounted above compressor and motor. Minimum space required.

HORIZONTAL AMMONIA COMPRESSO



Single and duplex; single-stage and two-sta belt drive or direct connected to electric mot diesel or steam engine; patented Feather valv ratings from 60 to 1000. Automatic capacity co trol features are easily applied.

ICE PLANTS

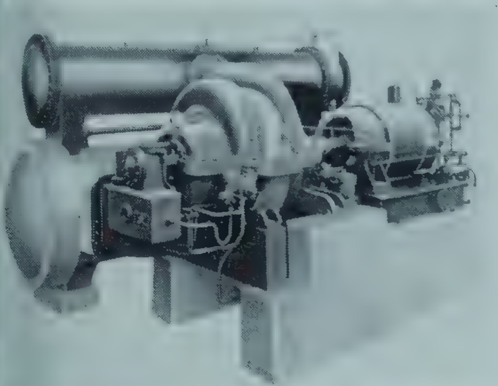
Ice plant equipment of all types, including co plete refrigeration machines with Worthing gas engine, diesel engine or steam drive in unit. Also, motor or belt driven compressors. tank with loose can or group lift. High trans coils in brine race or brine coolers as best sui

Ammonia Absorption Refrigeration Machinery

All Types of Auxiliary Equipment, Condensers, Coolers, Fittings, Etc.

Worthington Pump and Machinery Corp.

CENTRIFUGAL REFRIGERATION WATER COOLING SYSTEMS

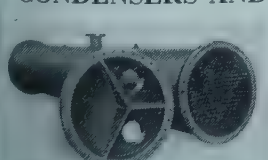


eon-11 centrifugal compressor, water cooler and ater-cooled condenser in compact unit assembly. ectric motor or steam turbine drive. 56 unit zes . . . 150 to 1200 tons.

EVAPORATIVE CONDENSERS

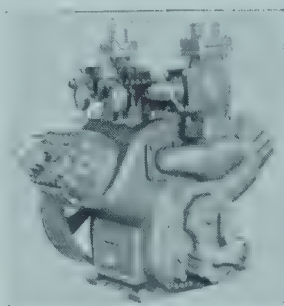
Series ECZ Freon-12 illustrated. 10 to 150 tons efrigeration. Units of sectionalized construction; ll parts easily accessible. Galvanized steel coils or ammonia. Bare copper coils for Freon-12.

CONDENSERS AND BRINE COOLERS



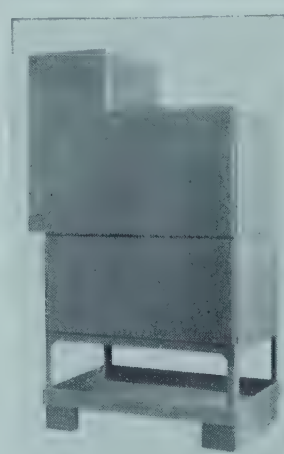
Multi-pass, as illustrated for closed systems and space saving. Heads efficiently baffled to produce high liquid velocity. Vertical "Spira-Flo" types provided with circular water box and special water distributors. Highly efficient, easily accessible for cleaning without interfering with condenser operation.

BOOSTER REFRIGERATION COMPRESSORS



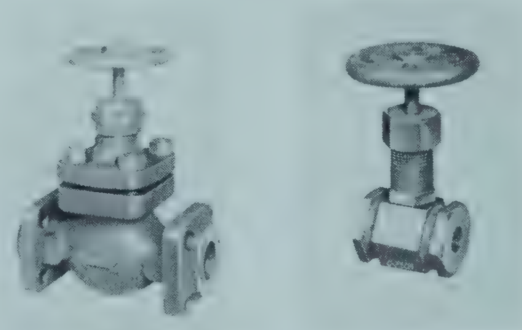
Multi-cylinder single-acting for capacities up to 400 cfm. Horizontal double-acting for larger capacity requirements. Designed to produce and maintain low evaporator pressures required for low temperature applications in conjunction with compression or absorption refrigeration systems.

PRODUCT COOLERS



Dry type units in many sizes and arrangements. Capacities from 2 to 10 tons. Air circulation rates from 2000 to 12000 cfm. Sectionalized construction with removable panels. Finned or bare pipe coils for use with Freon or Ammonia.

AMMONIA VALVES AND FITTINGS



Smaller sizes of all steel construction. Larger size valve bodies, ells and tees, close grained iron.

GAUGES, TEMPERATURE (See THERMOMETERS, DIAL)

GEAR MOTORS (See MOTORS, GEARHEAD)

GEARS

Chas. Bond Co., 617 Arch St., Phila., Pa.
Chicago Die Casting Mfg. Co., 2500 W. Monroe St., Chicago 12, Ill.
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
W. A. Jones Foundry & Machine Co., 4401 Roosevelt Rd., Chicago 24, Ill.
Link-Belt Co., 2045 W. Hunting Park, Phila. 40, Pa.
Palmer-Bee Co., 1701 Poland Ave., Detroit 12, Mich.
Philadelphia Gear Wks., Inc., G St. & Erie Ave., Phila. 20, Pa.
Ramsey Chain Co., Inc., 900 Broadway, Albany 1, N.Y.
Simonds Gear & Mfg. Co., 2501 Liberty Ave., Pittsburgh 22, Pa.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

GENERATORS (See ELECTRIC GENERATING PLANTS; also MOTOR GENERATORS)

GLASS

Semon Bache & Co., 636 Greenwich St., N.Y.C. 14
Dearborn Glass Co., 2414 W. 21st St., Chicago 8, Ill.
Hooker Glass & Paint & Mfg. Co., 659 W. Washington Blvd., Chicago, Ill.
Libbey-Owens-Ford Glass Co., Nicholas Bldg., Toledo 3, O.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.

GLASS BLOCKS

Hooker Glass & Paint & Mfg. Co., 659 W. Washington Blvd., Chicago, Ill.
Owens-Illinois Glass Co., Duraglas Bldg., Toledo 1, O.
Pittsburgh Corning Corp., 307-4th Ave., Pittsburgh 22, Pa.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Refractory & Insulation Corp., 120 Wall St., N.Y.C. 5

GLASS FILLERS (See DRINKING WATER COOLER FITTINGS)

GLASS, GAUGE (See GAUGE GLASSES)

GLASS, INSULATING OR HEAT DEFLECTING

Libby-Owens-Ford Glass Co., Nicholas Bldg., Toledo 3, O.
Pittsburgh Corning Corp., 307-4th Ave., Pittsburgh 22, Pa.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Thermopane Div., Libbey-Owens-Ford Glass Co., Nicholas Bldg., Toledo 3, O.

GLASS SPECIALTIES

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Semon Bache & Co., 636 Greenwich St., N.Y.C. 14
Carroll Glass Instrument Co., 6742 Lebanon Ave., Phila. 31, Pa.
Corning Glass Wks., Corning, N.Y.
Dearborn Glass Co., 2414 W. 21st St., Chicago 8, Ill.
Fischer & Porter Co., Hatboro, Pa.

GLYCOLS (See DIETHYLENE, ETHYLENE, & PROPYLENE GLYCOL)

GOVERNORS

Davis Regulator Co., 2511 S. Washtenaw Ave., Chicago 8, Ill.
Leslie Co., Lyndhurst, N.J.

GRAPHITE PRODUCTS (See also CARBON PRODUCTS)

Acheson Colloids Corp., Port Huron, Mich.
Graphite Metallizing Corp., 1050 Nepperhan Ave., Yonkers 3, N.Y.
Speer Carbon Co., St. Marys, Pa.
U. S. Graphite Co., Saginaw, Mich.

GREASE CUPS (See also LUBRICATORS)

Keystone Lubricating Co., 21st & Lippincott Sts., Phila. 32, Pa.
Link-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind.
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin'ti. 14, O.
Swift Lubricator Co., Inc., 101 Home St., Elmira, N.Y.

GREASES

Atlantic Refining Co., 260 S. Broad St., Phila., Pa.
Cities Service Oil Co. (Del.), 919 N. Michigan Ave., Chicago, Ill.
Cities Service Oil Co. (Pa.), 60 Wall Tower, N.Y.C. 5
Esso Standard Oil Co., 15 W. 51st St., N.Y.C. 19
Gulf Oil Corp., Gulf Bldg., Pittsburgh, Pa.
E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
Keystone Lubricating Co., 21st & Lippincott Sts., Phila. 32, Pa.
Lubriplate Div., Fiske Bros. Refining Co., 129 Lockwood St., Newark, N.J.
Macmillan Petroleum Corp., 530 W. 6th St , Los Angeles 14, Cal.
New York & New Jersey Lubricant Co., 292 Madison Ave., N.Y.C. 17
Shell Oil Co., Inc., 50 W. 50th St., N.Y.C. 20
Standard Oil Co. of California, 225 Bush St., San Francisco 20, Cal.
Sun Oil Co., 1608 Walnut St., Phila. 3, Pa.

GRILLES (See also AIR DIFFUSERS; also REGISTERS)

A-J Mfg. Co., 2119 Washington, Kansas City 8, Mo.
Air Control Products, Inc., Coopersville, Mich.
Anemostat Corp. of America, 10 E. 39th St., N.Y.C. 16 *(p. 19)*
Auer Register Co., 3608 Payne Ave., Cleveland, O.
Bahnson Co., 1001 S. Marshall St., Winston-Salem 7, N.C.
Barber-Colman Co., Rockford, Ill.
Best Register Co., 2005 W. Oklahoma Ave., Milwaukee 7 Wis.
Central Wire & Iron Wks., 621 E. Locust St., Des Moines 9, Ia.
Controlair Mfg. Co., 1932 S. Compton Ave., Los Angeles Cal.
Cyclone Fence Div., American Steel & Wire Co., U. S Steel Corp. Subsidiary, P.O. Box 260, Waukegan 1 Ill.
Diamond Mfg. Co., Wyoming, Pa.
Empire Ventilation Equipment Co., 35-39 Vernon Blvd. Long Island City 1, N.Y.
General Industries Co., Olive & Taylor Sts., Elyria, O.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Hart & Cooley Mfg. Co., 500 E. 8th St., Holland, Mich
Hendrick Mfg. Co., Carbondale, Pa.
Hupp Corp., 1250 W. 76th St., Cleveland 2, O.
Independent Register Co., 3747 E. 93rd St., Cleveland O.
Lockjoint Wood Products Co., 1721 Mildred Ave., Wichita 7, Kan.
Manhattan Perforated Metal Co., Inc., 43-17-37th St Long Island City 1, N.Y.
Newman Bros., Inc., 666 W. 4th St., Cin'ti. 3, O.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Pyle Nat'l. Co., 1371 W. 37th St., Chicago 9, Ill.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St Louis 6, Mo.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich
Amos Thompson Corp., Edinburg, Ind.
Titus Mfg. Corp., Waterloo, Ia.
Tuttle & Bailey, Inc., New Britain, Ct.
U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
U. S. Register Co., 344 E. Burnham St., Battle Creek Mich.
United Steel & Wire Co., Battle Creek, Mich.
Wheeling Corrugating Co., Wheeling, W. Va.
Young Regulator Co., 5209 Euclid Ave., Cleveland 3,

GROMMETS (See WASHERS; also RUBBER PRODUCTS, MOLDED)

GUARDS, FAN, MACHINERY, etc. (See also WIRE FORMING)

Buffalo Wire Wks., 3200 Terrace, Buffalo 2, N.Y.
Central Wire & Iron Wks., 621 E. Locust St., Des Moines 9, Ia.
Cyclone Fence Div., American Steel & Wire Co., U. S. Steel Corp., Subsidiary, P.O. Box 260, Waukegan 1, Ill.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Kentucky Metal Products Co., Preston St. & Audubon Park, Louisville 4, Ky.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Union Steel Products Co., 448 Pine St., Albion, Mich.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
United Welding Div., General Machinery Corp., 545 N 3rd St., Hamilton, O.

HAIR FELT (See FELT; also INSULATION, HAIR)

HAIR FOR INSTRUMENTS

Henry J. Green, 1191 Bedford Ave., Brooklyn 16, N.Y.

HANDLES, VALVE, etc.

Chicago Die Casting Mfg. Co., 2500 W. Monroe St., Chicago 12, Ill.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Diemolding Corp., Canastota, N.Y.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Walworth Co., 60 E. 42nd St., N.Y.C. 17

HANGERS, PIPE (See also CLAMPS, PIPE)

Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Behringer Metal Wks., Inc., 108 Jabez St., Newark 5, N.J.
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
Chicago Expansion Bolt Co., 1338 W. Concord Place, Chicago 22, Ill.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Grabler Mfg. Co., 6565 Broadway, Cleveland 5, O.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Minerallac Elec. Co., 25 N. Peoria St., Chicago 7, Ill.
Goodloe E. Moore Co., 2811 Vermilion, Danville, Ill.
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
M. B. Skinner & Co., South Bend 23, Ind. *(p. 104)*
Walworth Co., 60 E. 42nd St., N.Y.C. 17

HARDENING ROOMS (See ICE CREAM HARDENING ROOMS)

HARDWARE, COLD STORAGE DOOR

Arcade Mfg. Div., Rockwell Mfg. Co., 1212 E. Shawnee St., Freeport, Ill.
Butcher Boy Cold Storage Door Co., 170 N. Sangamon St., Chicago 7, Ill. *(p. 41)*
Chase Industrial Refrigerator Equip. & Engrg. Co., 630 Reading Rd., Reading, Cin'ti. 15, O.
Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
Grand Rapids Brass Co., 60 Scribner Ave., Grand Rapids, Mich.
Jamison Cold Storage Door Co., Hagerstown, Md.
Kason Hardware Corp., 127 Wallabout St., Brooklyn 6 N.Y.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City, Mo.
Mound Tool Co., 1203 S. 7th St., St. Louis 4, Mo.
Polar Hardware Co., 1631 S. Michigan Ave., Chicago 16, Ill.
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
V. E. Sprouse Co., Inc., Columbus, Ind.
Standard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12
Streator Products Corp., 508 N. 8th St., Fairfield, Ia.
York Corp., York, Pa. *(p. 119)*

HARDWARE, REFRIGERATOR

Arcade Mfg. Div., Rockwell Mfg. Co., 1212 E. Shawnee St., Freeport, Ill.
Chase Industrial Refrigerator Equip. & Engrg. Co., 630 Reading Rd., Reading, O.
Corbin Cabinet Co., Div. of American Hardware Corp., New Britain, Ct.
Dent Hardware Co., 1102-3rd St., Fullerton, Pa.
Grand Rapids Brass Co., 60 Scribner Ave., N.W., Grand Rapids 1, Mich.
Kason Hardware Corp., 127 Wallabout St., Brooklyn 6, N.Y.
Knape & Vogt Mfg. Co., Grand Rapids 4, Mich.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
Mound Tool Co., 1203 S. 7th St., St. Louis 4, Mo.
National Lock Co., 7th St. and 18th Ave., Rockford, Ill. *(p. 121)*
Polar Hardware Co., 1631 S. Michigan Ave., Chicago 16 Ill.
V. E. Sprouse Co., Inc., Columbus, Ind.
Standard-Keil Hardware Mfg. Co., Inc., 639 Broadway N.Y.C. 12

HARDWARE SPECIALTIES (See also specific item such as HOOKS, HINGES, etc.)

Arcade Mfg. Div., Rockwell Mfg. Co., 1212 E. Shawnee St., Freeport, Ill.
Croname, Inc., 3701 N. Ravenswood, Chicago 13, Ill.
Fox Co., Fox Lane, Cin'ti. 23, O.
L. F. Grammes & Sons, Inc., 365 Union St., Allentown Pa.
Grand Rapids Brass Co., 60 Scribner Ave., N.W., Grand Rapids 1, Mich.
Kason Hardware Corp., 127 Wallabout St., Brooklyn 6 N.Y.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
National Lock Co., 7th St. & 18th Ave., Rockford Ill. *(p. 121*
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
V. E. Sprouse Co., Inc., Columbus, Ind.
Standard-Keil Hardware Mfg. Co., Inc., 639 Broadway N.Y.C. 12
Stronghold Screw Products, Inc., 216 W. Hubbard St Chicago 10, Ill.
Swift Mfg. Co., Inc., 1455 E. Nine Mile Rd., Hazel Park Mich.

HARNESSES, ELECTRICAL (See WIRING DE VICES)

HEADS, TANK, etc. (See TANK HEADS)

HEAT EXCHANGERS

Acme Industries, Inc., Mechanic & Ganson Sts Jackson, Mich. *(p. 21*
Aerofin Corp., 410 Geddes St., Syracuse, N.Y. *(p. 1*
American Locomotive Co., 30 Church St., N.Y.C.
Richard M. Armstrong Co., Box 188, W. Chester, P *(p.*
Baker Refrigeration Corp., S. Windham, Me. *(p.*
Bell & Gossett Co., Morton Grove, Ill.
Betz Corp., 445 State St., Hammond, Ind.

(Continue

HEAT EXCHANGERS (Continued)

Bohn Aluminum & Brass Corp., E. Maumee, Adrian, Mich.
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
Cochrane Corp., 17th St., below Allegheny Ave., Phila. 32, Pa.
Cook Elec. Co., 2700 Southport Ave., Chicago 14, Ill.
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
Dole Refrigerating Co., 5910 N. Pulaski Rd., Chicago 30, Ill.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
Duriron Co., Inc., Dayton 1, O.
Eastern Industries, Inc., 296 Elm St., New Haven, Ct.
Fluor Corp., Ltd., 2500 S. Atlantic Blvd., Los Angeles 22, Cal.

Foster Wheeler Corp., 165 Broadway, N.Y.C.
Frick Co., Waynesboro, Pa. *(p. 4*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Heat-X-Changer Co., Inc., 415 Lexington Ave N.Y.C. 17 *(p. 12*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicag 7, Ill. *(p. 11*
Kelvinator Div., Nash-Kelvinator Corp., 142 Plymouth Rd., Detroit, Mich. *(p. 5*
Kirsch Co., Sturgis, Mich. (Hydrogen brazed)
Larkin Coils, 519 Memorial Dr , S.E., Atlanta 1, G *(p. 20*
Lehigh Fan & Blower Co., 128 Linden St., Allentow Pa.
Lummus Co., 420 Lexington Ave., N.Y.C.
Mueller Brass Co., Port Huron, Mich.
National Carbon Co., Inc., Unit of Union Carbide & Ca bon Corp., 30 E. 42nd St., N.Y.C. 17
Niagara Blower Co., 405 Lexington Ave., N.Y.C. *(p. 9*
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 5*
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsbur 1, Pa.
J. F. Pritchard & Co., 2200 Fidelity Bldg., Kans City 6, Mo. *(p. 7*
Quaker City Iron Wks., Aramingo Ave. & E. Tioga S Phila., Pa.
Remco, Inc., Zelienople, Pa. *(p. 10*
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimo 24, Md.
Rome-Turney Radiator Co., Rome, N.Y. *(p. 3*
Ross Heater & Mfg. Co., Div. of American Radiator Standard Sanitary Corp., Buffalo 13, N.Y.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinn Heating & Ventilating Co., Inc., 1948 N. 9th St., S Louis 6, Mo.
Standard Heater & Oil Equip. Co., 245 Cornelison Av Jersey City 2, N.J.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 1 Readville St., Boston 36, Mass. *(p. 1*
Superior Valve & Fittings Co., 1509 W. Liberty Av Pittsburgh 26, Pa. *(p. 12*
Temprite Products Corp., 47 Piquette Ave., Detr 2, Mich. *(p. 6*
H. A.Thrush & Co., 21 E. Riverside Dr., Peru, Ind.
Trane Co., La Crosse, Wis. *(p. 1*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis *(p. 4*
Votator Div., Girdler Corp., Louisville 1, Ky. (Mecha cal)
Wabash Mfg. Co., 2300 S. Western Ave., Chicago 8, I
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., C cago 51, Ill.
Worthington Pump & Machinery Corp., Harriso N.J. *(p. 11*
York Corp., York, Pa. *(p. 11*
Young Radiator Co., Racine, Wis. *(p.*

HEAT EXCHANGER TEES

Mueller Brass Co., Port Huron, Mich.

HEAT PUMPS (See CONDENSING UNITS)

T TREATING

ntic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
s Drop Forge Co., 209 W. Mt. Hope Ave., Lansing 2, Mich.
. Koven & Brother, Inc., 154 Ogden Ave., Jersey City 7, N.J.
o Products Co., 5711 W. Park Ave., St. Louis 10, Mo.

ATERS, & HEATING ELEMENTS, ELECTRIC

erican Instrument Co., 8010 Georgia Ave., Silver Spring, Md.
borundum Co., P.O. Box 337, Niagara Falls, N.Y.
tral States Mfg. Co., Inc., 1200 S. Summit, Arkansas City, Kan.
oid Equip. Co., Inc., 50 Church St., N.Y.C. 7
ler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
tromode Corp., 45 Crouch St., Rochester 3, N.Y.
tric Heater Co., Woodend Rd., Stratford, Ct.
son Equip. Co., 13th St., New Brighton, Pa.
eral Elec. Co., 1 River Rd., Schenectady 5, N.Y.
ttl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
nix Elec. Heater Co., 390-1st St., San Francisco 5, Cal.
stinghouse Elec. Corp., Meadville, Pa.
vin L. Wiegand Co., 7506 Thomas Blvd., Pittsburgh 8, Pa.

ATERS, AIR, GAS FIRED

ne Equip. Co., 205 E. Broadway, Muskogee, Okla.
yant Heater Co., 17825 St. Clair Ave., Cleveland 10, O.

ATING COILS (See AIR CONDITIONING COILS

ERMETIC COMPRESSORS (See CONDENSING UNITS)

ERMETIC HOUSINGS

klin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*

ERMETIC REFRIGERATING SYSTEMS

ecumseh Products Co., Tecumseh, Mich. *(p. 61)*

ERMETIC TERMINALS (See TERMINALS, HERMETIC)

IGHSIDE FLOATS (See also FLOAT SWITCHES)

A—Ammonia; B—Other refrigerants)

A,B) Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
B) Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*
A,B) Armstrong Machine Wks., 831 Maple St., Three Rivers, Mich. *(p. 164)*
A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
B) Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill *(p. 110)*
A,B) Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
A,B) H. A. Phillips & Co., 3255 W. Carroll Ave., Chicago 24, Ill. *(p. 141)*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
A) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
A,B) York Corp., York, Pa. *(p. 119)*

HINGES, REFRIGERATOR (See also HARDWARE)

Butcher Boy Cold Storage Door Co., 170 N. Sangamon St., Chicago 7, Ill. *(p. 41)*
Chase Industrial Refrigerator Equip. & Engrg. Co., 630 Reading Rd., Reading, Cin'ti. 15. O.
Grand Rapids Brass Co., 60 Scribner Ave., N.W., Grand Rapids 1, Mich.
Kason Hardware Corp., 127 Wallabout St., Brooklyn 6, N.J.
Knape & Vogt Mfg. Co., Grand Rapids 4, Mich.
Mound Tool Co., 1203 S. 7th St., St. Louis 4, Mo.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Polar Hardware Co., 1631 S. Michigan Ave., Chicago 16, Ill.

V. E. Sprouse Co., Inc., Columbus, Ind.
Standard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12
Stanley Wks., 195 Lake St., New Britain, Ct.
Veeder-Root, Inc., Garden & Sargeant Sts., Hartford 2, Ct.
E. R. Wagner Mfg. Co., 4001 N. 32nd St., Milwaukee, Wis

HOISTS (See CRANES)

HOME & FARM FREEZERS; FROZEN FOOD CABINETS (See also DISPLAY CASES, FROZEN FOOD)

Ace Cabinet Corp., 110 E. 42nd St., N.Y.C. 17
Amana Society, Amana, Ia.
American Refrigeration Corp., 2836 Colfax Ave., S., Minneapolis 8, Minn.
Artkraft Mfg. Corp., Kibby St. & D.T.&I.R.R., Lima, O.
Ben-Hur Mfg. Co., 634 E. Keefe Ave., Milwaukee 12, Wis.
R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Chapman & Wood Refrigeration, 4525 Southwest Pomona, Portland 19, Ore.
Cooleraton Co., 50 Ave W., and Wadena St., Duluth 1, Minn.
Crandal-Stone Div., Brewer-Titchener Corp., 336 Court St., Binghamton, N.Y.
Crosley Div., Arco Corp., Cin'ti. 25, O.
Cruse Refrigerator Co., Inc., 504 W. Main St., Louisville 2, Ky.
Deepfreeze Div., Motor Products Corp., 2301 Davis St., N. Chicago, Ill.
Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, Pa.
Esco Cabinet Co., West Chester, Pa.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.
Foster Refrigerator Corp., Mill & N. 2nd St., Hudson, N.Y.
Franklin Transformer Co., 65-22nd., N.E., Minneapolis 18, Minn.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., 1285 Boston Ave., Bridgeport 2, Ct.
General Refrigerator & Store Fixtures Co., 856 N. Broad St., Phila., Pa.
Gibson Refrigerator Co., 515 W. Williams St., Greenville, Mich.
Harder Refrigerator Corp., Div. of Tyler Fixture Corp., Cobleskill, N.Y.
John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
Holverson Co., 209 E. Lake St., Minneapolis 3, Minn.
Hotpoint, Inc., 5600 W. Taylor St., Chicago 44, Ill.
Hupp Corp., 1250 W. 76th St., Cleveland 2, O.
Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
Ideal Cooler Corp., 2953 Easton Ave., St. Louis 6. Mo.
International Harvester Co., 180 N. Michigan Ave., Chicago 1, Ill.
Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit Mich. *(p. 59)*
Leonard Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit 32, Mich.
McCall Refrigerator Corp., Hudson, N.Y.
McCray Refrigerator Co., Kendallville, Ind.
Master-Bilt Refrigeration Mfg. Co., 920 Palm St., St. Louis 7, Mo.
Masterfreeze Corp., Sister Bay, Wis.
Matthews Refrigerator & Door Co., 5103 S. E. Powell Blvd., Portland 6, Ore.
National Cooperatives, Inc., 343 S. Dearborn St. Chicago 4, Ill.
National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
Nelson Mfg. Co., 4016 N. Union St., St. Louis 15, Mo.
Nor-Lake, Inc., 2nd & Elm Sts., Hudson, Wis.
Pennco, Inc., 201 N. Broad St., Phila. 7, Pa.
Philco Corp., Tioga & C Sts., Phila. 34, Pa.
Portable Elevator Mfg. Co., 920 E. Grove St., Bloomington, Ill.
Revco, Inc., Deerfield, Mich.

(Continued)

HOME & FARM FREEZERS (Continued)

Rex Mfg. Co., Inc., Western Ave., Connersville, Ind.
Reynolds Metals Co., 2500 S. 3rd St., Louisville 1, Ky.
W. Allen Rogers Industries, Inc., P.O. Box 272, Demopolis, Ala.
Sanitary Refrigerator Co., Fond du Lac, Wis.
Savage Arms Corp., 311 Turner St., Utica 1, N.Y.
Schaefer, Inc., 801 Washington Ave., N., Minneapolis 1, Minn.
C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
Schwenger-Klein, Inc., 720 Bolivar Rd., Cleveland, O.
Seeger Refrigerator Co., 850 Arcade St., St. Paul 6, Minn.
Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
Simplex Mfg. Co., 1135-3rd St., Oakland 20, Cal.
Spir-O-Freez Co., Inc., 1077 Castleton Ave., Staten Island 10, N.Y.
Emil Steinhorst & Sons, Inc., 612 South St., Utica 3, N.Y.
Stoddard Mfg. Co., 617-4th St., S.W., Mason City, Ia.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
United Refrigerator Mfg. Co., Inc., 350 Robert St., St. Paul 1, Minn.
U. S. Thermo Control Co., 44 S. 12th St., Minneapolis 4, Minn.
Universal Refrigeration Co., 5601 W. Century Blvd., Inglewood, Cal.
Victor Products Corp., 901 Pope Ave., Hagerstown, Md
Warren Co., Inc., P.O. Box 1436, Atlanta 1, Ga.
Weber Showcase & Fixture Co., Inc., P.O. Box 2018, Los Angeles 54, Cal.
Wells & Brunnell Mfg. Co., Inc., P.O. Box 1555, Tacoma 1, Wash.
Western Mineral Products Co., 1720 Madison St., N.E., Minneapolis 13. Minn.
Westinghouse Elec. Corp., 653 Page Blvd., Springfield 2, Mass.
Whiting Corp., 38 S. Dearborn St., Chicago 3, Ill
Wilson Refrigeration, Inc., Div. of Wilson Cabinet Co., Inc., Smyrna, Del.
Yoder Corp., 133 W. 80th St., Cleveland 2, O.
York Corp., York, Pa. *(p. 119)*

HOOKS (See HARDWARE SPECIALTIES)

Knape & Vogt Mfg. Co., Grand Rapids 4, Mich.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City, Mo.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
National Lock Co., 7th St. & 18th Ave. Rockford, Ill. *(p. 121)*
V. E. Sprouse Co., Inc., Columbus, Ind.
Standard-Keil Hardware Mfg. Co., Inc., 639 B'way, N.Y.C. 12
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.

HOSE, FLEXIBLE METAL (See also CHARGING LINES; also FLEXIBLE CONNECTIONS; also TUBING, FLEXIBLE)

Aeroquip Corp., 300 S. East Ave., Jackson, Mich.
American Brass Co., Waterbury 83, Ct. *(p. 199)*
Atlantic Metal Hose Co., Inc., 124 W. 64th St., N.Y.C. 23
Chicago Metal Hose Corp., Maywood, Ill.
Eclipse Aviation Metal Hose Dept., Div. of Bendix Aviation Corp., Phila. 44, Pa.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill
Flexible Tubing Corp., N. Main St., Branford, Ct.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Johnson Metal Hose Co., 226 Mill St., Waterbury 88, Ct.
Packless Metal Products Corp., 31 Winthrop Ave., New Rochelle, N.Y. *(p. 217)*
Resistoflex Corp., 39 Plansoen St., Belleville 9, N.J.
Seamlex Co., Inc., 4123-24th St., Long Island City 1, N.Y.
Titeflex, Inc., 500 Frelinghuysen Ave., Newark 5, N.J.
John M. Watt's Sons, 112 Walnut St., Phila., Pa.

HOSE, RADIATOR, WATER, AIR, etc.

H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
Darcoid Co., Inc., 145-6th Ave., N.Y.C. 13
DeVilbiss Co., 300 Phillips Ave., Toledo 1, O.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
Flexible Tubing Corp., N. Main St., Branford, Ct.
Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Hudson Products Co., Inc., 4400 St. Aubin, Detroit 7, Mich.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Thermoid Co., Trenton, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
John M. Watt's Sons, 112 Walnut St., Phila., Pa.

HOSE CLAMPS (See FITTINGS, HOSE)

HUMIDIFIERS & HUMIDIFYING SYSTEMS (See also SPRAY HUMIDIFIERS)

Abbeon Supply Co., 58-10-41st Drive, Woodside, N.Y.C.
Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 17
American Blower Corp., Div. of American Radiator & Standard Sanitary Corp., 8111 Tireman Ave., Detroit 32, Mich.
American Coils Co., 25 Lexington St., Newark 5, N.J.
American Instrument Co., 8010 Georgia Ave., Silver Spring, Md.
Anetsberger Bros., Northbrook, Ill.
Armstrong Machine Wks., 831 Maple St., Three Rivers, Mich. *(p. 16…)*
Bahnson Co., 1001 S. Marshall St., Winston-Salem …, N.C.
Bowser, Inc., Terryville, Ct.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 4…)*
Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Drying Systems, Inc., 1810½ Foster Ave., Chicago 40, Ill.
Farr Co., 2615 Southwest Dr., Los Angeles, Cal.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Grinnell Co., Inc., 260 W. Exchange St., Providence …, R.I.
McDonnell & Miller, Inc., 1316 Wrigley Bldg., Chicago 11, Ill.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
National Air Conditioning, Inc., Johnstown, Pa.
National Engrg. & Mfg. Co., 519 Wyandotte, Kansas City 8, Mo.
Parks-Cramer Co., Box 444, Fitchburg, Mass.
Fred D. Pfening Co., 1075 W. 5th Ave., Columbus 8, O.
Rhode Island Humidifier & Ventilating Co., 99 Chauncy St., Boston 11, Mass.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
H. J. Somers, Inc., 6063 Wabash Ave., Detroit 8, Mich.
Spraying Systems Co., 3201 Randolph St., Bellwood, Chicago, Ill.
B. F. Sturtevant Div. Westinghouse Elec. Corp., 101 Readville St., Boston 39, Mass. *(p. 1…)*
Supreme Elec. Products Co., 194 Vassar St., Rochester …, N.Y.
Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.
Techtman Industries, 714 W. Wisconsin Ave., Milwaukee 1, Wis.
Viking Air Conditioning Corp., 5600 Walworth Ave., Cleveland 2, O.
Water Cooling Corp., 71 Nassau St., N.Y.C. 7
Stanley Wertheim & Son, 58-01-41st Dr., Woodside, N.Y.C.
York Corp., York, Pa. *(p. 11…)*

HUMIDISTATS (See CONTROLS, HUMIDITY)

HYDROCARBONS

Carbide & Carbon Chemicals Corp., Unit. of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17

HYDROGEN

Air Reduction Sales Co., 60 E. 42nd St., N.Y.C. 17
Linde Air Products Co., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17

ANS

an Rolling Mill Co., Middletown, O.
Co., Waynesboro, Pa. *(p. 44)*
erbocker Stamping Co., Parkersburg, W. Va.
eel Products, Inc., 740 N. Plankinton Ave., Milaukee 3, Wis.
Products Div., Refrigeration Engrg. Corp., 2020 audain St., Phila. 46, Pa.
hington Pump & Machinery Corp., Harrison, .J. *(p. 116)*
Corp., York, Pa. *(p. 119)*

REAM CABINETS

abinet Corp., New Bedford, Mass.
can Refrigeration Corp., 2836 Colfax Ave., S., Mineapolis, Minn.
ıser Busch, Inc., 9th & Wyoming, St. Louis, Mo.
n-Blessing Co., 4201 W. Peterson Ave., Chicago 40, l.
Bishop & Co., 103 N. 2nd St., Champaign, Ill.
man & Wood Refrigeration, 425 Southwest Pomona, ortland 19, Ore.
lal-Stone Div., Brewer-Titchener Corp., 336 Court t., Binghamton, N.Y.
Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
daire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
n Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
nator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
d Carbonic Corp., 3100 S. Kedzie Ave., Chicago 23, ll.
teel Products, Inc., 740 N. Plankinton Ave., Milvaukee 3, Wis.
Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. *(p. 60)*
n Mfg. Co., 4016 N. Union St., St. Louis 15, Mo.
co, Inc., 201 N. Broad St., Phila. 7, Pa.
geration Corp. of America, Div. of Lonergan Mfg. Co., Albion, Mich.
ge Arms Corp., 311 Turner St., Utica 1, N.Y.
efer, Inc., 801 Washington Ave., N., Minneapolis 1, Minn.
les Q. Sherman Corp., 149 Broadway, N.Y.C. 6
en Freezer Mfg. Co., 3401-17th Ave., W., Seattle 99, Wash.
i-Craft, 845-5th, Beloit, Wis.
ry Thompson Machine & Supply Co., 1349 Inwood Ave., N.Y.C. 52
ill Pump Co., 939 E. 95th St., Chicago 19, Ill.
er Showcase & Fixture Co., Inc., P.O. Box 2018, Los Angeles 54, Cal.

CREAM FREEZERS

ian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
rry-Burrell Corp., 427 W. Randolph St, Chicago 6, Ill.
amery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
rsteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
ls Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. *(p. 60)*
den Freezer Mfg. Co., 3401-17th Ave., W., Seattle 99, Wash.
lor Freezer Corp., Beloit, Wis. (Counter)
ni-Craft, 845-5th, Beloit, Wis.
ery Thompson Machine & Supply Co., 1349 Inwood Ave., N.Y.C. 52
hill Pump Co., 939 E. 95th St., Chicago 19, Ill.
versal Refrigeration Co., 5601 W. Century Blvd., Inglewood, Cal.
ator Div., Girdler Corp., Louisville 1, Ky.

CREAM HARDENING CABINETS

stian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
apman & Wood Refrigeration, 4525 Southwest Pomona, Portland 19, Ore.
ndal-Stone Div., Brewer-Titchener Corp., 336 Court St., Binghamton, N.Y.
ans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
lverson Co., 209 E. Lake St., Minneapolis 3, Minn.
lls Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. *(p. 60)*

National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo. (Sectional Construction)
Nelson Mfg. Co., 4016 N. Union St., St. Louis 15, Mo.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Schaefer, Inc., 801 Washington Ave., N., Minneapolis 1, Minn.
Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
Sweden Freezer Mfg. Co., 3401-17th Ave. W., Seattle 99, Wash.
Taylor Freezer Corp., Beloit, Wis.
Tekni-Craft, 845-5th, Beloit, Wis.
Emery Thompson Machine & Supply Co., 1349 Inwood Ave., N.Y.C. 52
Tuthill Pump Co., 939 E. 95th St., Chicago 19, Ill.
Universal Refrigeration Co., 5601 W. Century Blvd., Inglewood, Cal.

ICE CREAM HARDENING ROOMS

Chapman & Wood Refrigeration, 4525 Southwest Pomona, Portland 19, Ore.
Cork Insulation Co., 155 E. 44th St., N.Y.C. 17
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo. (Sectional Construction)
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
Sweden Freezer Mfg. Co., 3401-17th Ave., W., Seattle 99, Wash.
Wilson Refrigeration, Inc., Div. of Wilson Cabinet Co., Inc., Smyrna, Del.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

ICE CUBE CUTTERS

Gifford-Wood Co., Hill St., Hudson, N.Y.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Thermo Cuber Co., Inc., Melrose Park, Ill.

ICE CUBE FREEZING LOWSIDES

(A—Ammonia; B—Other refrigerants)
(B) Betz Corp., 445 State St., Hammond, Ind.
(B) Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. *(p. 200)*
(A,B) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
(B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(B) Holverson Co., 209 E. Lake St., Minneapolis 3, Minn.
(B) Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. *(p. 202)*
(A,B) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
(A,B) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(A,B) Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
(B) Simplex Mfg. Co., 1135-3rd St., Oakland 20, Cal.
(B) Standard Refrigeration Co., 232 S. Hoyne Ave., Chicago 20, Ill.
Super-cold Corp., 1020 E. 59th St., Los Angeles, Cal.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(B) United Refrigerator Mfg. Co., Inc., 350 Robert St., St. Paul 1, Minn.
(B) Warren Co., Inc., P.O. Box 1436, Atlanta 1, Ga.
(B) York Corp., York, Pa. *(p. 119)*

ICE CUBE MACHINES, SELF-CONTAINED

Ajax Corp., Evansville, Ind.
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Ice-Flo Corp., Mill St., Providence, R.I.
Mills Industries, Inc., 4100 Fullerton Ave., Chicago 39, Ill. *(p. 60)*
McQuay, Inc., 1000 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
York Corp., York, Pa. *(p. 119)*

ICE CUBE TRAYS

Aluminum Goods Mfg. Co., Manitowoc, Wis.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Hoosier Cardinal Corp., 601 E. Eichel Ave., Evansville 7, Ind.
Inland Mfg. Div., Gen'l. Motors Corp., Dayton 1, O.
Mack Molding Co., Ryerson Ave., Wayne, N.J.
Plastray Corp., 823 Fisher Bldg., Detroit 2, Mich.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Harry Zysman, Inc., 427 E. 146th St., N.Y.C. 55 *(p. 126)*

ICE MAKERS, BULK

Bemco Mfg. Corp., 1504 Minor at Pike, Seattle 1, Wash.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Esco Cabinet Co., West Chester, Pa.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Holverson Co., 209 E. Lake St., Minneapolis 3, Minn.
La Crosse Cooler Co., 2809 Losey Blvd., S., La Crosse, Wis.
R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Victor Products Corp., 901 Pope Ave., Hagerstown, Md.
Wilson Refrigeration, Inc., Div. of Wilson Cabinet Co., Inc., Smyrna, Del.

ICE MAKING MACHINES, AUTOMATIC (See also ICE CUBE MAKING MACHINES)

Belt-Ice Corp., 2845-16th Ave., W., Seattle 99, Wash.
Flakice Corp., 360 Furman St., Brooklyn 2, N.Y.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.

Nor-Lake, Inc., 2nd & Elm Sts., Hudson, Wis.
Orley Freezers, Inc., 680 E. Fort St., Detroit 26, M
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7,
Henry Vogt Machine Co., 10th & Ormsby St., Lou 10, Ky.
Worthington Pump & Machinery Corp., Har N.J. (p
XL Refrigerating Co., 1834 W. 59th St., Chicago
York Corp., York, Pa. (p

ICE MANUFACTURING ACCESSORIES (See ICE CANS)

Baker Refrigeration Corp., S. Windham, Me
California Steel Products Co., Barrett & "A" Sts., mond, Cal.
Frick Co., Waynesboro, Pa.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23,
Gifford-Wood Co., Hill St., Hudson, N.Y.
Jamison Cold Storage Door Co., Hagerstown, Md.
Knickerbocker Stamping Co., Parkersburg, W.Va.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Jos. A. Martocello & Co., 229 N. 14th St., Ph Pa. (p
Reco Products Div., Refrigeration Engrg. Corp. Naudain St., Phila. 46, Pa.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7,
Worthington Pump & Machinery Corp., Har N.J. (p
York Corp., York, Pa. (p

INDICATORS (See particular type, i.e., RATE; LIQUID; LEAK; MOISTURE, etc.)

INHIBITORS, CORROSION (See also W. TREATING)

American Chemical Paint Co., Ambler, Pa.
American Sand-Banum Co., Inc., 9 Rockefeller N.Y.C. 20
Aquatic Chemical Labs., Inc., 95 Liberty St., N.Y.
Henry Bower Chemical Mfg. Co., Gray's Ferry 29th St., Phila. 46, Pa.
Carbide & Carbon Chemicals Corp., Unit of Unior bide & Carbon Corp., 30 E. 42nd St., N.Y.C.
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.
Chemical Solvent Co., Box 487, Birmingham, Ala.
Dearborn Chemical Co., 310 S. Michigan Ave., Ch Ill.
Doctor Boiler, Inc., 4316 Main St., Dallas, Tex.
Elgin Softener Corp., Elgin, Ill.
Ferro-Nil Corp., 381-4th Ave., N.Y.C. 16
D. W. Haering & Co., 205 W. Wacker Dr., Chicag
E. F. Houghton & Co., 303 W. Lehigh Ave., Phila.
Midland Paint & Varnish Co., 3801 E. 91st St., Cle 5, O.
National Aluminate Co., 6216 W. 66th Place cago 38, Ill. (p
New Jersey Zinc Co., 160 Front St., N.Y.C. 7
North American Fibre Products Co., Standard Cleveland 13, O.
Nox-Rust Chemical Corp., 2429 S. Halsted St., C 8, Ill.
Oakite Products, Inc., 22 Thames St., N.Y.C. 6
O'Brien Industries, 84 Bishop St., Jersey City 4, N
Permutit Co., 330 W. 42nd St., N.Y.C. 18
Perolin Co., Inc., 10 E. 40th St., N.Y.C. 16
Pittsburgh Plate Glass Co., 632 Duquesne Way, burgh 22, Pa.
Sta-Rite Products Co., Inc., Delavan, Wis.
Tempo Chemical Co., Inc., 4-88-47th Ave., Long City 1, N.Y.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2,
Western Chemical Co., 713 Washington St., Kans 6, Mo.
Wilbur-Williams Co., 43 Leon St., Boston, Mass.

INJECTORS, REFRIGERANT

Cold Control, Inc., 111 Broadway, N.Y.C. 6
H. A. Phillips & Co., 3255 W. Carroll Ave., Ch 24, Ill.

ERTS FOR MOLDING, etc. (See FASTENERS; also HARDWARE SPECIALTIES)

TRUMENT PANELS

er Refrigeration Co., S. Windham, Me. *(p. 48)*
stol Co., Waterbury 91, Ct.
ndler Co., 1407 Park St., Hartford 6, Ct.
roit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
strom Co., 13 Falstrom Court, Passaic, N.J.
cher & Porter Co., Hatboro, Pa.
ude S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
rshalltown Mfg. Co., Marshalltown, Ia.
os Thompson Corp., Edinburg, Ind.

SULATING PLASTER & CONCRETE

bcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
bert A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
nn and Steele, Inc., 130 Lister Ave., Newark 5, N.J.
tional Gypsum Co., 325 Delaware Ave., Buffalo 2, N.Y.
ctor Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
igley Co., Inc., 527-5th Ave., N.Y.C. 17
fractory & Insulation Corp., 120 Wall St., N.Y.C. 5
iversal Zonolite Insulation Co., 135 S. La Salle St., Chicago 3, Ill.
estern Mineral Products Co., 1720 Madison St., N.E., Minneapolis 13, Minn.

SULATION, AEROGEL

errimac Div., Monsanto Chemical Co., Everett 49, Mass.

INSULATION, ASBESTOS, MAGNESIA, etc.

Acme Asbestos Covering & Flooring Co., 236 N. Elizabeth St., Chicago 7, Ill.
Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17 *(p. 135)*
Armstrong Cork Co., Lancaster, Pa. *(p. 131)*
Atlas Asbestos Co., Ltd., 110 McGill St., Montreal 1, Quebec, Canada
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Keasbey & Mattison Co., Ambler, Pa.
Mundet Cork Corp., 7101 Tonnelle Ave., N. Bergen, N.J. *(p. 129)*
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Ruberoid Co., 500-5th Ave., N.Y.C. 18

(Continued)

Jointite
TRADE MARK
COLD INSULATION

MUNDET CORKBOARD

Mundet Products

intite" Corkboard for cold insulation; "Jointite" Moulded Cork Pipe Covering and Fitting Cov- for cold pipe lines; intite" Cork Lagging; ndet Natural Cork Iso- on Mats for preventing nsmission of vibration; intite" Cork Roof insu- ion and all varieties of h grade cork specialties; % Magnesia Pipe Cover- and Block Insulation.

Mundet "Jointite" Corkboard

bricated from 100% pure rk—complies with U.S. vernment Master Speci- ations. Unsurpassed for cold insulation services: ld storage rooms; ice tanks; sharp freezers; roofs; frigerators; refrigerator cars and trucks. Recom- ended for acoustical correction. Manufactured in ly one grade, "Jointite" is the most economical cause it is the highest grade corkboard obtain- le. Standard size: 12" x 36", thickness ½", ¾", 1", , 3", 4" and 6". Estimates furnished with or ithout our installation.

Mundet "Jointite" Cork Pipe Covering

uickly applied; the most economical cold pipe sulation on a value basis. Mineral rubber finish ves protection from moisture or frost.

View of Mundet "Jointite" Cork Pipe Covering, with moulded fitting cover

MUNDET CORK PIPE COVERING

Made in 3 thicknesses, for all types and sizes of cold lines carrying sub-zero to 50° temperature. In sections 36" long with standard fitting covers.

Mundet "Jointite" Beveled Cork Lagging

Cut to order to any desired radius, effectively insulates all types of cylindrical tanks and coolers.

Mundet Services Cover the Whole Job

Avoid divided responsibility by permitting us to arrange for the complete installation of Mundet Insulation. We maintain an efficient, trained erecting staff at all of our branch offices. All materials and workmanship are guaranteed and no contract is too large or too small to receive expert handling.

Our engineering department is at your service at all times to assist and advise in the preparation of specifications pertaining to Cork. This service is available to any one who has an insulation problem, and does not obligate you.

Write for the Mundet Cork Catalog

The latest edition contains valuable insulation information, including heat loss chart and important specification data. Send for your free copy.

Mundet Cork Corporation

7101 Tonnelle Ave. — Insulation Division — North Bergen, N.J.

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Our offices are equipped to supply and install a full line of low and high temperature insulation material.

anada: MUNDET CORK & INSULATION, LTD., Montreal, Que., Toronto, Ont., Winnipeg, Man., Vancouver, B. C.

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Standard Asbestos Mfg. Co., 860 W. Evergreen Ave., Cl cago 22, Ill.
Standard Asbestos Mfg. & Insulation Co., 410 N. Oli St., Kansas City 1, Mo.
Taft-Jenkins Co., Inc., 27 Sargeant St., Holyoke, Ma

INSULATION, BALSA

Balsa Ecuador Lumber Corp., 500-5th Ave., N.Y.C.
Geo. D. Emery Co., 220-11th Ave., N.Y.C. 1
International Balsa Corp., 96 Boyd Ave., Jersey City N.J.

INSULATION, CELLULAR RUBBER

B. F. Goodrich Co., 500 S. Main St., Akron, O.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo N.Y.
Sponge Rubber Products Co., Howe Ave., Shelton, Ct.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C.
Rubatex Div., Great American Industries, In Bedford, Va. *(p. 1*

INSULATION, CELLULOSE FIBRE

Celotex Corp., 120 S. La Salle St., Chicago 3, Ill.
Hinde & Dauch Paper Co., P.O. Box 86, Sandusky, O.
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Kimberly-Clark Corp., Neenah, Wis.
Masonite Corp., 111 W. Washington St., Chicago 2, Ill
B. F. Nelson Mfg. Co., 401 Main St., N.E., Minneapo 13, Minn.
Plastergon Wall Board Co., Box 40, Sta. B, Buffalo N.Y.
Wood Conversion Co., First Nat'l. Bank Bldg., S Paul 1, Mass *(p. 1*

INSULATION, CORK

Armstrong Cork Co., Lancaster, Pa. *(p. 1*
Cork Import Corp., 39 Park Place, Englewood, N.J.
Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago Ill.
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
La Suberina, S.A., San Feliu de Guixols (Catalonia) Sp
Albert O. Lloveras, 143 Waverly Place, N.Y.C. 14
Mundet Cork Corp., 7101 Tonnelle Ave., N. Berge N.J. *(p. 1*
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y. 17 *(p. 1*
United Cork Cos., Kearny, N.J. *(p. 1*

INSULATION, COTTON

Plastergon Wall Board Co., Box 40, Sta. B, Buffalo N.Y.
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, K

INSULATION, EXPANDED VERMICULITE

Ehret Magnesia Mfg. Co., Valley Forge, Pa.
International Vermiculite Co., Girard, Ill.
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
B. F. Nelson Mfg. Co., 401 Main St., N.E., Minneap 13, Minn.
Universal Zonolite Insulation Co., 135 S. La Salle St., C cago 3, Ill.
Western Mineral Products Co., 1720 Madison St., N. Minneapolis 13, Minn.

INSULATION, FIBERGLAS

Owens-Corning Fiberglas Corp., 2012 Nichol Bldg., Toledo 1, O. *(p. 1*

INSULATION, FOAM GLASS

Armstrong Cork Co., Lancaster, Pa. *(p.*
Pittsburgh Corning Corp., 307-4th Ave., Pittsburgh Pa.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pitt burgh 22, Pa.

Armstrong Cork Company

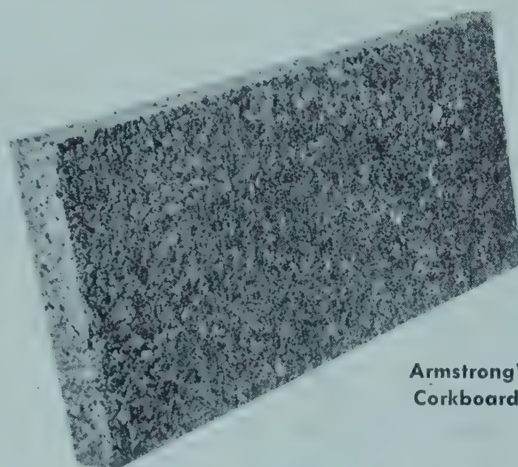
938 Concord Street, Lancaster, Pa.
Offices and distributors in principal cities

ARMSTRONG'S LOW-TEMPERATURE INSULATIONS

ARMSTRONG'S CORKBOARD

Thermal conductivity: 0.27 at 60° F.
Weight: Averages .60 to 0.65 lb. per bd. ft.
Sizes: 12" x 36", 18" x 36," 24" x 36", 36" x 36".
Thicknesses: 1", 1½", 2", 3", 4", and 6".

General: Armstrong's Corkboard is made entirely of pure cork granules, compressed into board form. This material is strong and tough yet easy to handle and install. It will not settle, sag, shrink, or warp; is fire-retardant, and will not harbor vermin. Portland cement plaster and asphalt emulsion finishes bond securely to corkboard surfaces. Armstrong's Corkboard conforms to Federal Specifications HH-C-561 b.

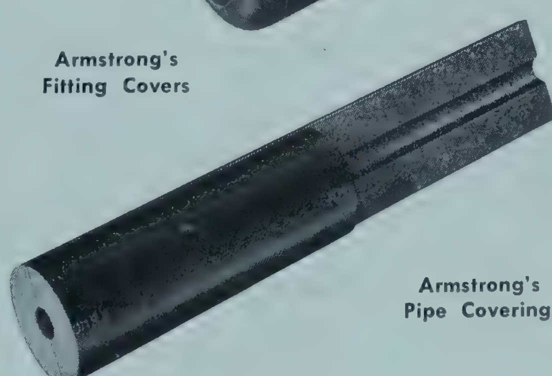


Armstrong's Corkboard

ARMSTRONG'S CORK COVERING

Armstrong's Cork Pipe Covering and Fitting Covers possess essentially the same physical characteristics as Armstrong's Corkboard. They are compressed and baked in molds, machined to accurate size, and finished with a heavy mastic coating which provides a seal against air and moisture penetration. Pipe covering is made in 36" half-sections, in Heavy, Standard, and Light-Duty thicknesses, for pipe sizes from ¼" up. Fitting covers are made in corresponding thicknesses for all types of ells, tees, valves, flanges, unions, etc. Armstrong's Cork Covering will also be made to customer's specifications for jobs requiring special sizes, thicknesses and shapes.

Armstrong's Fitting Covers



Armstrong's Pipe Covering

COMPLETE CONTRACT SERVICE

Armstrong's Contract Service provides materials, installation crews, and engineering assistance for all types of low-temperature insulation jobs. For complete information about the products and services offered by this nation-wide organization, contact your nearest Armstrong office or write direct to Armstrong Cork Company, 938 Concord Street, Lancaster, Pa.

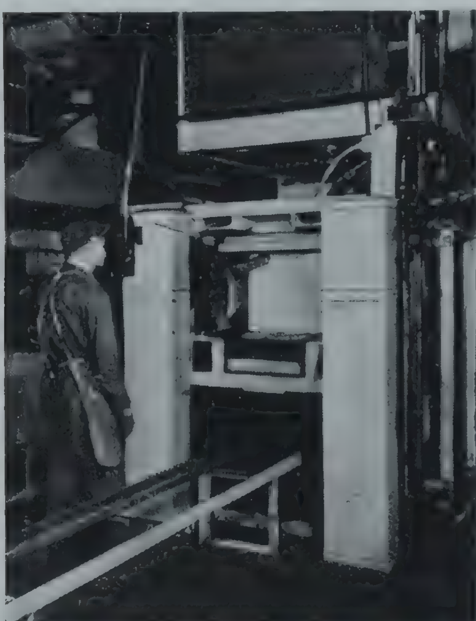
Wood Conversion Company

Dept. 200-0, First National Bank Building, St. Paul 1, Minn.

New York Denver Chicago

K-25 INSULATION FIBER*

PNEUMATIC SYSTEM FOR REFRIGERATOR CABINETS



Installation

K-25 Fiber*, applied by the Wood Conversion Company's high-speed pneumatic system, makes it possible to insulate sealed type refrigerator cabinets and doors in a few seconds, with positive automatic control and elimination of all joints, laminations and voids.

K-25 Fiber was scientifically developed by Wood Conversion Company to meet the need for streamlined production of domestic refrigerators. Shipped in highly compressed, easily stored bales, K-25 is quickly processed to the proper low density in your own plant—then blown into cabinets and doors under high pressure. Made of clean, new wood fiber, K-25 has an unusually low "k" factor. It is moisture resistant, clean and odorless. Because of its high felting qualities and resilience, K-25 Fiber will not settle.

CABINETS AUTOMATICALLY INSULATED

In the K-25 Fiber Pneumatic System, the refrigerator is automatically insulated under pressure with the insulating fiber conforming to the contour of the outer shell of the cabinet. In the blowing operation, a dummy liner or fixture is used. The fiber completely fills the space between liner and outer shell. In other words, the Pneumatic System introduces the bulk insulating fiber into the cabinet or door and builds or "casts" a self-sustaining mat without the use of any binder. This is made possible by the characteristics of the K-25 Fiber, which are its ability to felt and maintain resiliency.

*Trade-Mark

Refrigerator door pneumatically insulated with K-25 Fiber

United Cork Companies

Manufacturers, Engineers and Contractors for Refrigeration and Air Conditioning Insulation; Sound and Vibration Absorption

Kearny, N.J.

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St. Louis, Mo.
Waterville, Me.

COMPANY

Pioneers in corkboard manufacture and advanced erection methods, UNITED has served thousands of insulation users for almost fifty years. The manufacturing plant at Kearny, N.J., is considered one of the most modern establishments of its kind.

UNITED'S B.B. (BLOCK-BAKED) CORKBOARD

UNITED'S B.B. Corkboard Insulation guards against moisture condensation, and severe climatic conditions which may affect the proper protection of perishable food products.

The high efficiency of UNITED'S B.B. (Block-Baked) Corkboard is due to its remarkable heat retarding properties . . . entire freedom from capillarity . . . and other inherent qualities. The character, composition, and chemical construction of natural cork, as provided by nature, make it unsurpassed as a cold storage and refrigerator insulator.

In cold rooms, UNITED'S B.B. (Block-Baked) Corkboard, because of its low conductivity value, helps maintain predetermined temperatures and humidity control. The result is less overloading of the vital refrigerating equipment . . . assuring more efficient operation, and longer life.

UNITED'S B.B. Corkboard is pure cork, made to U.S. Bureau of Standard's specifications. Adaptable to all construction. Easy to handle. Sanitary, remains dry, will not rot or mold. Write for UNITED'S B.B. Corkboard Catalog.

RE-GRANULATED CORK

For loose-fill, refrigerated spaces, etc.

UNITED'S ROOF CORKBOARD INSULATION

Keeps upper floors warmer in winter (reduces heat loss), cooler in summer; eliminates condensation of moisture on the underside of ceilings thus saving spoilage of products.

SERVICE ORGANIZATION

Complete branch and warehouse facilities are located in cities listed above. UNITED'S Service Engineers travel from these branch offices, within limits, and will gladly confer with architects, contractors, and engineers in regard to designing, preparing drawings, specifications, etc., on jobs requiring cork.

NATURAL GRANULATED CORK

Primarily used for plastic mixes, stuffings, compositions, etc.

CORK PIPE COVERING

For brine, ammonia, ice or cold lines. Pipe covering and fitting jackets are molded to fit absolutely tight.

CORK-FLOORINGS For banks, offices, etc.

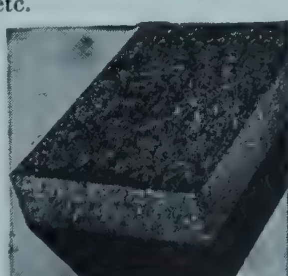
UNITED CORK LAGGING Beveled to any desired radius for covering cylindrical equipment.

UNITED'S CORK COMPOSITION For gasketing, sealings, shoes, novelties, etc.

ISOLATION CORKBOARD For absorbing vibrations and noise caused by pumps, fans, compressors, generators, motors, presses, etc.

CORK SPECIALTIES For specific application.

UNITED'S ACOUSTICAL CORKBOARD



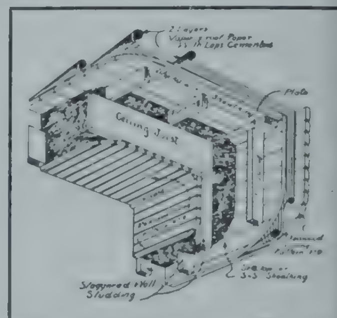
UNITED'S "Acousticork" is usually applied 1½ in. thick. Has high sound absorption co-efficiency. Combines noise quieting with high insulating value. Easy to install. Structurally strong. Can be painted to harmonize with decorative scheme. High light reflection when painted. Flexible.

Write for "Acousticork" Catalog.

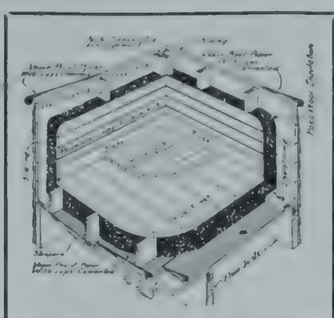
Specify PALCO INSULATION WOOL

FOR UNIFORM LOW TEMPERATURE CONTROL

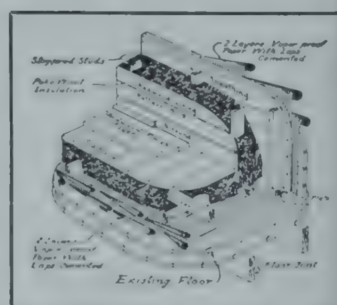
WHEN building or expanding frozen food lockers and cold storage plants, experienced refrigeration engineers know PALCO WOOL Insulation meets the most rigid and exacting requirements of non-settling permanence, long-life endurance, low thermal conductivity and fire resistance. Produced from the bark of California Redwoods, PALCO WOOL Insulation is inherently moisture resistant, odor proof, and vermin repellent. Readily adaptable to all types of construction, PALCO WOOL Insulation not only keeps operating costs at a minimum through its high efficiency, but also effects savings in capital charges by reducing plant investment and depreciation. Investigate today how to get continuing economies with PALCO WOOL Insulation. Write for full details.



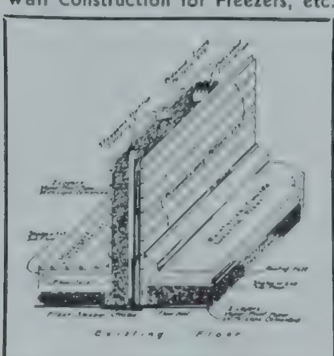
Typical Wall and Ceiling Wood Finish Construction for Low Temperatures.



Standard Wood Finish Floor and Wall Construction for Freezers, etc.



Normal Frame Construction, Wood Walls, Flooring, and Exterior Siding for Cold Storage.



Accepted Partition Construction between Freezer and Cooler with Wood Finish Wall and Floor, and Concrete Chill Floor.

CHECK THESE SUPERIOR QUALITIES OF PALCO WOOL INSULATION

- √ **Low Thermal Conductivity**
- √ **Durable**
- √ **Moisture Resistant**
- √ **Vermin Repellent**
- √ **Non-Settling**
- √ **Flame-Proofed**
- √ **Odor-Proof**
- √ **Economical**

For Typical Construction Details Write Today for the *New* Cold Storage *Manual*

THE PACIFIC LUMBER COMPANY

100 BUSH STREET, SAN FRANCISCO 4, CALIFORNIA

35 E. Wacker Drive
Chicago 1, Illinois

5225 Wilshire Blvd.
Los Angeles 36, California

American Flange & Manufacturing Co. Inc.

30 Rockefeller Plaza, New York 20, N.Y.
Plaza 7-2200

Ferro-Therm

Reg. U.S. Pat. Off.

STEEL INSULATION

Fully protected by U.S. and Foreign Patents
Issued and Pending

Ferro-Therm installed in a cold storage room

Ferro-Therm Steel Insulation, made from rigid steel sheets with a special alloy coating, reflects 90 per cent to 95 per cent of all radiant heat. This high reflectivity, combined with extremely low heat storage capacity, provides maximum insulating efficiency in minimum overall thickness.

Saves Pay Space and Weight

In cold storage construction, the number of sheets of Ferro-Therm depends on the temperature to be maintained and the U value required. The k value of Ferro-Therm, based on tests, is listed in the Data Book of the *American Society of Refrigerating Engineers* as 0.226 Btu per (hr) (sq ft) (°F temperature difference). Laboratory tests and thousands of applications have demonstrated that a wall of Ferro-Therm will provide insulating efficiency equivalent to a wall of mass insulation approximately twice as thick.

Assures Rapid Pull Down of Temperature

The low heat storage capacity of Ferro-Therm is extremely important in achieving rapid pull down of temperature, and in saving refrigeration costs for the initial and each subsequent cooling of space. Specifically, the heat storage capacity of a single sheet of No. 38 gauge is 0.029 Btu per (hr) (sq ft) (°F temperature difference). This is approximately 1/16 of the heat storage capacity of 1 sq ft of 1 in. thickness corkboard.

Permanent, Fire-Proof Insulation

Ferro-Therm construction eliminates trapping of moisture condensate, with subsequent deterioration of the construction. As it is all-metal, Ferro-Therm cannot be penetrated by rodents, vermin or termites, and is absolutely non-combustible. The value of Ferro-Therm for fire protection is apparent.

125° Below Zero Maintained in Altitude Test Chambers

Ferro-Therm has proved its superiority in buildings, cold storage rooms, refrigerated cabinets, locker rooms, dry ice containers, refrigerated railway car construction, ovens, high-temperature storage tanks—in fact, practically every type of application where high insulating efficiency with economies in space and weight are a requisite. The most notable demonstration of Ferro-Therm performance has been its selection for the insulation of altitude chambers for the testing of Army and Navy aviation equipment and personnel. In these chambers, temperatures as low as −125°F were maintained, with a temperature drop of +70°F to −70°F in 10 to 12 min.

Our catalog, giving data and installation details on Ferro-Therm, will be sent upon request.

RUBATEX
INSULATION HARDBOARD
The Ideal Low Temperature Insulation

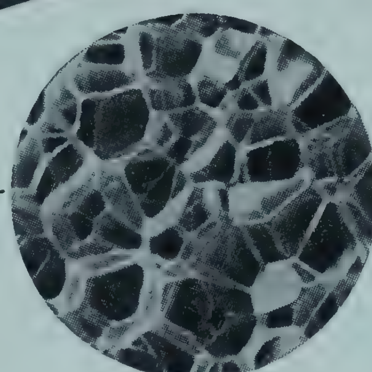


Photo-micrograph of a section of RUBATEX Insulation Hardboard shows the dense structure of individually sealed cells which give this product its exceptional insulating properties.

- **K factor 0.21**
- **Zero moisture pick-up**
- **No vapor barrier needed**

This product is an expanded cellular rubber in board form. Its many exceptional characteristics make it outstanding as a low temperature insulating material.

Light weight—4½ lbs. per cubic foot
Excellent structural strength
Compressive strength—60 lbs. per square inch
Rot, vermin and termite proof
Exceptionally long life
Does not crumble or settle
Easy to handle
Standard board sizes—17½″ x 35½″
Thicknesses—1″, 1½″, 2″, 3″

RUBATEX Soft Cellular Rubber for Gaskets

Expanded rubber. Nitrogen filled, sealed cells. Zero moisture absorption. Resists oxidation. Low thermal conductivity. Can be die cut or molded.

Additional information and catalogs available upon request

Great American Industries, Inc., RUBATEX DIVISION, BEDFORD, VA.

INSULATION, HAIR PRODUCTS

American Felt Co., Glenville, Ct.
American Hair & Felt Co., 222 N. Bank Dr., Chicago 54, Ill.
Armstrong Cork Co., Lancaster, Pa. *(p. 131)*
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
Johns-Manville, 22 E 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Sponge Rubber Products Co., 106 Derby Place, Shelton Ct.

INSULATION, MINERAL WOOL

Alton Mineral Wool Insulation Co., 2317 Whitemore Place, St. Louis 4, Mo.
Armstrong Cork Co., Lancaster, Pa. *(p. 131)*
Baldwin-Hill Co., 500 Breunig Ave., Trenton 2, N.J.
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Carney Co., Inc., 153 Chestnut St., Mankato, Minn.
Cork Import Corp., 39 Park Place, Englewood, N.J.
Eagle-Picher Sales Co., American Bldg., Cin'. 1, O.
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
Johns-Manville, 22. E. 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Mundet Cork Corp., 7101 Tonnelle Ave., N. Bergen, N.J. *(p. 129)*
National Gypsum Co., 325 Delaware Ave., Buffalo 2, N.Y.
Owens-Corning Fiberglas Corp., 2012 Nicholas Bldg. Toledo 1, O. *(p. 139)*
Plastergon Wall Board Co., Box 40, Sta. B, Buffalo 7, N.Y.
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Standard Asbestos Mfg. Co., 860 W. Evergreen Ave., Chicago 22, Ill.

INSULATION, PIPE & TUBE (See also specific type of INSULATION)

A. G. Brauer Supply Co., 2100 Washington Ave., St. Louis 3, Mo.
Cork Import Corp., 39 Park Place, Englewood, N.J.

Eagle-Picher Sales Co., American Bldg., Cin'ti 1, O.
Fleetwood-Airflow, Inc., 421 N. Penna Ave., Wilkes-Barre, Pa.
Robt. A. Keasley Co., 139 W. 19th St., N.Y.C. 11
J. W. Mortell Co., Burch St., Kankakee, Ill.
Mundet Cork Corp., 7101 Tonnelle Ave., N. Bergen, N.J. *(p. 129)*
Mystik Adhesive Products, Div. of Chicago Show Printing Co., 2635 Kildare Ave., Chicago 39, Ill.
National Gypsum Co., 325 Delaware Ave., Buffalo 2 N.Y.
North Penn Co., 72-5th Ave., N.Y.C. 11
R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
Pittsburgh-Corning Corp., 307-4th Ave., Pittsburgh 22, Pa.
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
Sponge Rubber Products Co., Howe St., Shelton, Ct.
Taft-Jenkins Co., Inc., 27 Sargeant St., Holyoke, Mass.
United Cork Cos., Kearny, N.J. *(p. 133)*

INSULATION, PLASTIC FOAM

Dow Chemical Co., Midland, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.

INSULATION, REDWOOD BARK

Pacific Lumber Co., 100 Bush St., San Francisco 4 Cal. *(p. 134)*
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C 17 *(p. 138)*

INSULATION, REFLECTIVE TYPE

Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17 *(p. 135)*
American Flange & Mfg. Co., 30 Rockefeller Plaza N.Y.C. 20 *(p. 136)*
C. T. Hogan & Co., Inc., 383 Madison Ave., N.Y.C. 17
Infra Insulation, Inc., 10 Murray St., N.Y.C. 7
Permanente Products Co., 1924 B'way, Oakland 12, Cal
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.
Reynolds Metals Co., Reynolds Metals Bldg., Richmond 19, Va.
Sisalkraft Co., 205 W. Wacker Drive, Chicago 6, Ill.
Sub Zero, Inc., 41 E. 42nd St., N.Y.C. 17

INSULATION CLIPS

Devices, Inc., 214 E. 53rd St., N.Y.C. 22
Lexington Supply Co., 4815 Lexington Ave., Cleveland 2, O.
Miracle Adhesives Corp., 214 E. 53rd St., N.Y.C. 22
Stic-Klip Mfg. Co., 50 Regent St., Cambridge 40 Mass. *(p. 127)*

INSULATION ERECTION MATERIALS

American Bitumuls Co., 200 Bush St., San Francisco 4 Cal.
Cork Import Corp., 39 Park Place, Englewood, N.J.
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
International Balsa Corp., 96 Boyd Ave., Jersey City 4 N.J.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Miracle Adhesives Corp., 214 E. 53rd St., N.Y.C. 22
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10 Mo.
Rector Mineral Trading Corp., 164 E. 43rd St., N.Y.C 17 *(p. 138)*
Rubatex Div., Great American Industries, Bedford Va. *(p. 137)*
Stancal Asphalt & Bitumuls Co., 200 Bush St., San Francisco 4, Cal.
Stic-Klip Mfg. Co., 50 Regent St., Cambridge 40 Mass. *(p. 127)*
United Cork Cos., Kearny, N.J. *(p. 133)*

INTERCOOLERS

Richard M. Armstrong Co., Box 188, W. Chester, Pa *(p. 52)*

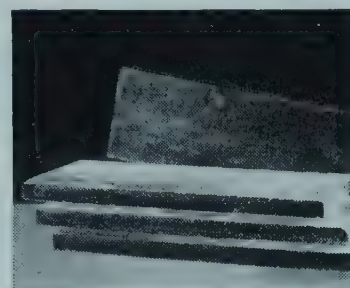
(Continued)

OWENS-CORNING FIBERGLAS *Insulations*

FOR EVERY LOW-TEMPERATURE NEED

FIBERGLAS PF (Pre-Formed) INSULATION
Widely used for low-temperature structures and refrigerated equipment. Available in seven standard densities from 2½ to 10½ lbs. per cu. ft.

FIBERGLAS PF PIPE INSULATION
Fiberglas Insulating Wool preformed in sections to fit standard pipe sizes up to 30". AEROCOR PF-310 — A lightweight, flexible, blanket-type insulation for use around fittings, valves, nested pipes.



FIBERGLAS AE (Asphalt-Enclosed) BOARD
Made of a core of Fiberglas PF (Pre-Formed) Insulation completely enclosed with an asphalt coating. Easy to cut and install. Size: 12" x 36". Available in 6 lb. or 9 lb. cu. ft. density.

In all of its many easy-to-use forms, Fiberglas* Insulation is a "natural" for maintaining low temperatures with utmost economy in a wide variety of applications.

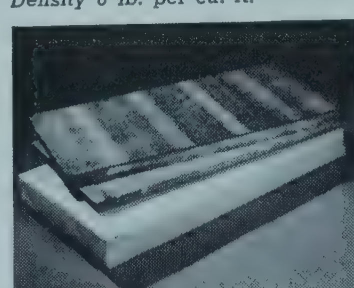
Made of ageless fibers of glass, the thermal insulation efficiency of these Fiberglas Products is exceptionally high. Fiberglas materials neither produce nor pick up odors in service. They are highly moisture-resistant, impervious to mildew and won't rot or sustain vermin.

Light in weight, Fiberglas Insulation has good mechanical strength—doesn't settle, dust or disintegrate under vibration. Mechanics like to apply it because it is easy to cut and handle.

Write for complete technical information and application data concerning Fiberglas Insulations for low-temperature service to Owens-Corning Fiberglas Corporation, Dept. 103, Toledo 1, Ohio. Or, write or phone the Fiberglas Branch Office nearest you.

**Fiberglas is the trade-mark (Reg. U. S. Pat. Off.) of Owens-Corning Fiberglas Corporation for a variety of products made of or with glass fibers.*

FIBERGLAS AE-F (Floor) BOARD
Offering greater resistance to compressive loads, this asphalt enclosed Fiberglas Insulation Board is designed specifically for use as a floor insulation in low-temperature structures. Size: 12" x 36". Density 6 lb. per cu. ft.



FIBERGLAS ROOF INSULATION
Provides a firm, structurally sound material as the underlying layer of insulation in built-up roofs of low-temperature structures. Easily applied by standard methods. Exceptionally low thermal conductances. Size: 24" x 48". Thickness: ½" to 2".

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INTERCOOLERS (Continued)

Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 *(p. 122)*
Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Standard Heater & Oil Equip. Co., 245 Cornelison Ave., Jersey City 2, N.J.
York Corp., York, Pa. *(p. 119)*

IRON, ENAMELING (See SHEET, ENAMELING)

IRON PIPE COILS (See PIPE COILS, BENDS & BENDING)

ISOBUTANE

Carbide & Carbon Chemicals Corp., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17

JARS, REFRIGERATOR

Ball Bros. Co., Muncie, Ind.
Amos Thompson Corp., Edinburgh, Ind.

JOINTS (See particular type, i.e., EXPANSION; SWING, etc.)

KEYS, MACHINE, WOODRUFF, etc.

Holo-Krome Screw Corp., 25 Brook St., Hartford 10, Ct
Standard Steel Specialty Co., Beaver Falls, Pa.

KNOBS, CONTROL, etc.

American Emblem Co., Inc., 9 Genesee St., New Hartford Utica 1, N.Y.
Chicago Die Casting Mfg. Co., 2500 W. Monroe St., Chicago 12, Ill.
Cutler-Hammer, Inc., 315 N. 12 St., Milwaukee 1, Wis.
Diemolding Corp., Canastota, N.Y.
General Industries Co., Olive & Taylor Sts., Elyria, O.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Standard Molding Corp., 1517 E. 3rd St., Dayton 1, O.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J.

LABELS, METAL (See NAME PLATES)

LACQUERS (See FINISHES)

LAMPS, BACTERICIDAL, GERMICIDAL, ULTRA-VIOLET, etc.

Alexander-Tagg Industries, Inc., Jacksonville Rd. & Summit Ave., Hatboro, Pa.
Coleman-Petterson Corp., 2130 St. Clair Ave., Cleveland 14, O.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hanovia Chemical & Mfg. Co., Chestnut St. & N.J.R.R. Ave., Newark 5, N.J.
Sperti, Inc., Norwood Sta., Cin'ti. 12, O.
Sylvania Electric Products, Inc., 500-5th Ave., N.Y.C. 18
Ultra-Violet Products, Inc., 145 Pasadena Ave., S. Pasadena, Cal.
Westinghouse Elec. Corp., McArthur Ave., Bloomfield, N.J.

LAMPS, ELECTRIC

General Elec. Co., Nela Park, Cleveland 12, O
Westinghouse Elec. Corp., Bloomfield, N.J.

LAPPING

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill. (Contract)

LARD CHILLERS

Koch Butchers' Supply Co., 600 E. 14th Ave., N., Kansas City 16, Mo.
Votator Div., Girdler Corp., Louisville 1, Ky.

LEAK DETECTORS

Consolidated Engrg. Corp., 620 N. Lake Ave., Pasadena 4, Cal.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Justrite Mfg. Co., 2061 N. Southport Ave., Chicago 14, Ill.
Kobbe Labs., 114 E. 32nd St., N.Y.C. 16
Linde Air Products Co., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Turner Brass Wks., Sycamore, Ill.
Ultra-Violet Products, Inc., 145 Pasadena Ave., S. Pasadena, Cal.

LEAK INDICATORS

Allin Mfg. Co., 1153 W. Grand Ave., Chicago, Ill.
Highside Chemicals Co., 10 Colfax Ave., Clifton, N.J.

LEATHER SPECIALTIES (See also WASHERS, LEATHER)

Chicago Belting Co., 113 N. Green St., Chicago 7, Ill.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
Fisher Leather Belting Co., Inc., 325 N. 3rd St., Phila. 6, Pa.
Graton & Knight Co., 356 Franklin St., Worcester 4, Mass.
Chas. A. Schieren Co., 30 Ferry St., N.Y.C. 7
Southern Belting Co., 236 Forsyth St., S.W., Atlanta 2, Ga.

LIDS, CABINET, etc. (See CABINET TOPS & LIDS)

LIGHTING PLANTS (See ELECTRIC GENERATORS)

LIGHTING, ULTRA-VIOLET (See LAMPS, BACTERICIDAL)

LINERS, REFRIGERATOR

R. H. Bishop Co., 103 N. 2nd St., Champaign, Ill.
Crandal-Stone Div., Brewer-Titchener Corp., 336 Court St., Binghamton, N.Y.
Motors Metal Mfg. Co., 5936 Milford Ave., Detroit 10, Mich.
Panelyte Div., St. Regis Paper Co., 230 Park Ave., N.Y.C 17
Standard Products Co., 505 Blvd., Bldg., Detroit 2, Mich.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber)

LINING, REFRIGERATOR

Pacific Lumber Co., 100 Bush St., San Francisco 4, Cal. *(p. 134)*
Tylac Co., Greeley & High St., Monticello, Ill.

LIQUID COOLERS (See BRINE COOLERS; also WATER COOLERS, etc.)

LIQUID INDICATORS

Allin Mfg. Co., 1153 W. Grand Ave., Chicago, Ill.
Frick Co., Waynesboro, Pa. *(p. 44)*
Henry Valve Co., Melrose Park, Ill. *(p. 115)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Lunkenheimer Co., Beekman St., & Waverly Ave., Cin'ti 14, O.
Madden Brass Products Co., 1111 N. Franklin St., Chicago 10, Ill.
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
Mueller Brass Co., Port Huron, Mich.
Nathan Mfg. Co., 416 E. 106th St., N.Y.C. 29
Remco, Inc., Zelienople, Pa. *(p. 107)*
Cyrus Shank Co., 625 W. Jackson Blvd., Chicago 6, Ill.

Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 122)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.

LIQUID LEVEL CONTROLS (See CONTROLS, LIQUID LEVEL; also HIGHSIDE FLOATS; also LOWSIDE FLOATS; also FLOATS; also FLOAT SWITCHES)

LIQUID LEVEL INDICATORS (See GAUGES, LIQUID LEVEL)

LITHIUM BROMIDE

Dow Chemical Co., Midland, Mich.
Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.

LITHIUM CHLORIDE

Mallinckrodt Chemical Wks., 2nd & Mallinckrodt St., St. Louis, Mo.
Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.

LOCKERS

All-Steel Equip., Inc., Kensington Ave., Aurora, Ill
Frick Co., Waynesboro, Pa. *(p. 44)*
Frosty Foods Equip. Co., 305 Benson Blvd., Sioux City 15, Ia.
Knickerbocker Stamping Co., Parkersburg, W. Va.
Locker Engrg. Co., 521 N. La Cienga Blvd., Los Angeles 36, Cal.
Master Mfg. Corp., 119 Main St., Sioux City 4, Ia.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.

LOCK NUTS (See NUTS, LOCK)

LOCK WASHERS (See WASHERS, LOCK)

LOCKS

Corbin Cabinet Lock Div., New Britain, Ct.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Standard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12

LOUVRED BAFFLES (See COIL & BAFFLE ASSEMBLIES)

LOUVRES (See also SHUTTERS)

Air & Refrigeration Corp., 475-5th Ave., N.Y.C. 12
Arex Co., 333 N. Michigan Ave., Chicago 1, Ill.
Burt Mfg. Co., 932 S. High St., Akron 11, O.
E. K. Campbell Heating Co., 1809 Manchester St., Kansas City 3, Mo.
Diamond Mfg. Co., Wyoming, Pa.
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
Electrovent Fan & Mfg. Co., 812 W. Lake St., Chicago 7, Ill.
General Industries Co., Olive & Taylor Sts., Elyria, O.
Lockjoint Wood Products Co., Wichita 7, Kan.
Midget Louver Co., 7 Wall St., Norwalk, Ct.
Herman Nelson Corp., 1824-3rd Ave., Moline, Ill.
H. H. Robertson Co., 2400 Farmers Bank Bldg., Pittsburgh 22, Pa.
Amos Thompson Corp., Edinburgh, Ind.

LOWSIDE EQUIPMENT (See particular type)

LOWSIDE FLOATS (See also FLOAT SWITCHES)
(A—Ammonia; B—Other refrigerants)

(A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
(B) Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
(A,B) King-Zeero Co., 1447 Montrose Ave., Chicago 13, Ill. *(p. 149)*
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
(A,B) H. A. Phillips & Co., 3255 W. Carroll Ave., Chicago 24, Ill. *(p. 141)*
(A,B) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(A) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
(A,B) York Corp., York, Pa. *(p. 119)*

LUBRICANTS (See GREASES, OILS)

LUBRICATORS & LUBRICATING SYSTEMS (See also GREASE CUPS)

Alemite Div., Stewart-Warner Corp., 1826 Diversey Pkwy., Chicago 14, Ill.
Bijur Lubricating Corp., 43-01-22nd St., Long Island City 1, N.Y.
Bowser, Inc., 1302 E. Creighton Ave., Ft. Wayne 2, Ind.
Consolidated Brass Co., 139 Summit, Detroit 9, Mich.
Farval Corp., 3263 E. 80th St., Cleveland 4, O.
Frick Co., Waynesboro, Pa. *(p. 44)*
Hills McCanna Co., 3029 N. Western Ave., Chicago 18, Ill.
Keystone Lubricating Co., 21st & Lippincott Sts., Phila. 32, Pa.
Lincoln Engrg. Co., 5701 Natural Bridge Ave., St. Louis, Mo.
. E. Lonergan Co., 2nd & Race Sts., Phila. 6, Pa.
unkenheimer Co., Beekman St. & Waverly Ave., Cin'ti. 14, O.
Madison-Kipp Corp., 201 Waubesa St., Madison 4, Wis.
Manzel, Inc., 309 Babcock St., Buffalo 10, N.Y.
Nathan Mfg. Co., 416 E. 106th St., N.Y.C. 29
C. A. Norgren, 222 Santa Fe Drive, Denver, Col.
Wm. W. Nugent & Co., Inc., 410 Hermitage Ave., Chicago 22, Ill.
Oil Rite Corp., 3466 S. 13th St., Milwaukee 7, Wis.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Swift Lubricator Co., Inc., 101 Home St., Elmira, N.Y.
Trabon Engrg. Corp., 1814 E. 40th St., Cleveland 30, O.
Trico Fuse Mfg. Co., 2948 N. 5th St., Milwaukee 2, Wis.

LUGS, TANKS

Arrow Tank Co., Inc., 16 Barnett St., Buffalo 15, N.Y.
Lakeside Malleable Castings Co., Racine, Wis.

MAGNESIUM CHLORIDE

Dow Chemical Co., Midland, Mich.

MAGNETIC VALVES (See SOLENOID VALVES)

MANIFOLDS

Frick Co., Waynesboro, Pa. *(p. 44)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 218)*
Mueller Brass Co., Port Huron, Mich.
Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 122)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.

MANOMETERS

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Builders-Providence, Inc., P.O. Box 1342 Providence 1, R.I.
Hays Corp., Michigan City, Ind.
Meriam Instrument Co., 10920 Madison Ave., Cleveland 2, O.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.

MARGARINE CHILLERS (See LARD CHILLERS)

MATERIAL HANDLING EQUIPMENT (See CONVEYORS)

MEDALLIONS (See NAME PLATES)

MEMBRANES (See VAPOR SEALS)

MESH, METAL (See also WIRE CLOTH)

Buffalo Wire Wks., 3200 Terrace, Buffalo 2, N.Y.
Cambridge Wire Cloth Co., Cambridge, Md.
Central Wire & Iron Wks., 621 E. Locust St., Des Moines 9, Ia.
Cyclone Fence Div., American Steel & Wire Co., U. S Steel Corp. Subsidiary, P.O. Box 260, Waukegan 1, Ill.
Kentucky Metal Products Co., Preston St. & Audubon Park, Louisville 4, Ky.
Newark Wire Cloth, 351 Verona Ave., Newark 4, N.J.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
Wheeling Corrugating Co., Wheeling, W. Va.
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp., 500-5th Ave., N.Y.C. 18

METAL SPECIALTIES (See also particular item)

Acme Equip. Co., 205 E. Broadway, Muskogee, Okla.
Alexander-Tagg Industries, Inc., Jacksonville Rd. & Summit Ave., Hatboro, Pa.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Cambridge Wire Cloth Co., Cambridge, Md.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Greene Mfg. Co., Inc., 1025 Douglas Ave., Racine, Wis.
Heintz Mfg. Co., Front St. & Olney Ave., Phila. 20, Pa.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee, Wis.
Northern Engraving & Mfg. Co., 4th & Vine Sts., La Crosse, Wis.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Robinson Aviation, Inc., Teterboro, N.J.
Standard-Keil Hardware Mfg. Co., 639 Broadway, N.Y.C. 12
V. E. Sprouse Co., Inc., Columbus, Ind.

METAL SPINNING

L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Maysteel Products, Inc., 135 W. Wells St., Milwaukee 3, Wis.
Superior Spinning & Stamping Co., 4057 Fitch Rd., Toledo 12, O.

METAL STAMPING (See STAMPINGS)

METAL, BEARING (See BEARING MATERIALS)

METAL, LAMINATED

General Plate Div., Metals & Controls Corp., Attleboro, Mass.

METAL, PERFORATED

Bristol Brass Corp., Bristol, Ct.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago Perforating Co , 2445 W. 24th Place, Chicago 8, Ill.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
Diamond Mfg. Co., Wyoming, Pa.
Erdle Perforating Co., 171 York St., Rochester 11, N.Y.
Harrington & King Perforating Co., 5655 Fillmore St., Chicago 44, Ill.
Manhattan Perforated Metal Co., Inc., 43-17-37th St., Long Island City 1, N.Y.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Robins Conveyors Div., Hewitt-Robins, Inc., Passaic, N.J.
U. S. Register Co., 344 E. Burnham St., Battle Creek, Mich.

METAL, THERMOSTATIC (See THERMOSTATIC BI-METALS)

METERS, BRINE

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Builders-Providence, Inc., P.O. Box 1342 Providence 1, R.I.
Fischer & Porter Co., Hatboro, Pa.
Neptune Meter Co., 50 W. 50th St., N.Y.C. 20
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

METERS, COIN OPERATED

General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
International Register Co., 2620 W. Washington Blvd., Chicago 12, Ill.

METERS, ELECTRIC

Bristol Co., Waterbury 91, Ct. (Recording)
Esterline-Angus Co., Inc., P.O. Box 596, Indpls. 6, Ind.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Sangamo Elec. Co., Springfield, Ill.
Westinghouse Elec. Corp., Plane & Orange Sts., Newark 1, N.J.
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

METERS, FLOW

American District Steam Co., Bryant St., N. Tonawanda, N.Y.
Badger Meter Mfg. Co., Milwaukee 10, Wis.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Builders-Providence, Inc., P.O. Box 1342, Providence 1, R.I.
Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
Fischer & Porter Co., Hatboro, Pa.
Hays Corp., Michigan City, Ind.
Henszey Co., 202½ N. Water St., Watertown, Wis.
Meriam Instrument Co., 10920 Madison Ave., Cleveland 2, O.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Pittsburgh Equitable Meter Div., Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Schutte & Koerting Co., 12th & Thompson St., Phila. 22, Pa.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.

METERS, RECORDING

Badger Meter Mfg. Co., Milwaukee 10, Wis.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Builders-Providence, Inc., Div., P.O. Box 1342, Providence 1, R.I.
Esterline Angus Co., Inc., P.O. Box 596, Indpls. 6, Ind.
Fischer & Porter Co., Hatboro, Pa. (Flow Rate)
Hays Corp., Michigan City, Ind.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Westinghouse Elec. Corp., Plane & Orange Sts., Newark 1, N.J.

METERS, REFRIGERANT

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Fischer & Porter Co., Hatboro, Pa.
Neptune Meter Co., 50 W 50th St., N.Y.C. 20

METERS, RUNNING TIME

Bristol Co., Waterbury 91, Ct.
R. W. Cramer Co., Box 25, Centerbrook, Ct. *(p. 194)*
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

METERS, VENTURI

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.

METHYL CHLORIDE

Ansul Chemical Co., Marinette, Wis. *(p. 167)*
Dow Chemical Co., Midland, Mich.
Electrochemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Eston Chemicals, Inc., 3100 E. 26th St., Los Angeles 23, Cal.
Great Western Div., Dow Chemical Co., 310 Sansome St., San Francisco 4, Cal.
Virginia Smelting Co., W. Norfolk, Va. *(p. 168)*

METHYLENE CHLORIDE

Ansul Chemical Co., Marinette, Wis. *(p. 167)*
Dow Chemical Co., Midland, Mich.
Electrochemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Eston Chemicals, Inc., 3100 E. 26th St., Los Angeles 23, Cal.
Virginia Smelting Co., W. Norfolk, Va. *(p. 168)*

MILK COOLERS, CABINET TYPE

R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
Esco Cabinet Co., West Chester, Pa.
Ideal Cooler Corp., 2953 Easton Ave., St. Louis 6, Mo.
International Harvester Co., 180 N. Michigan Ave., Chicago 1, Ill.
La Crosse Cooler Co., 2809 Losey Blvd., S., La Crosse, Wis.
Master-Bilt Refrigeration Mfg. Co., 920 Palm St., St Louis 7, Mo.
National Cooperatives, Inc., 343 S. Dearborn St., Chicago 4, Ill.
W. Allen Rogers Industries, Inc., P.O. Box 272, Demopolis, Ala.
Emil Steinhorst & Sons, Inc., 612 South St., Utica 3 N.Y.
Victor Products Corp., 901 Pope Ave., Hagerstown, Md.
Wilson Refrigeration, Inc., Div. of Wilson Cabinet Co., Inc., Smyrna, Del.

MIRRORS

Hooker Glass & Paint & Mfg. Co., 659 W. Washington Blvd., Chicago, Ill.
Semon Bache & Co., 636 Greenwich St., N.Y.C. 14

MOISTURE INDICATORS

Davison Chemical Corp., Baltimore 3, Md. *(p. 79)*
McIntire Connector Co., 252 Jefferson St., Newark 5, N.J. *(p. 84)*

MOLDED PRODUCTS, PLASTIC

Bakelite Corp., 30 E. 42nd St., N.Y.C. 17
Cambridge Molded Plastics Co., Cambridge, O.
Chicago Molded Products Corp., 1020 N. Kolmar Ave., Chicago, Ill.
Crescent Plastics, 303 1st Ave., Evansville, Ind.
General American Transportation Corp., 135 S. La Salle St., Chicago 90, Ill.
General Electric Co., 100 Woodlawn Ave., Pittsfield, Mass.
Kent Plastics Corp., 1528 N. Fulton Ave., Evansville, Ind.
Mack Molding Co., Arlington, Vt.
Plaskon Div., L-O-F Glass Co., Sylvan Ave., Toledo, O.
Prolon Plastics, Florence, Mass.
Standard Molding Corp., 1517 E. 3rd St., Dayton 1, O.
Standards Products Co., 316 Fisher Bldg., Detroit 2, Mich.
Amos Thompson Corp., Edinburg, Ind.
Wolverine Plastics, Inc., 495 Redman Rd., Milan, Mich.

MONEL (See also mill forms, i.e., SHEET, etc.)

International Nickel Co., 67 Wall St., N.Y.C. 5

MONORAILS (See CONVEYORS, MONORAIL)

MORTUARY REFRIGERATORS (See REFRIGERATORS, MORTUARY)

MOTOR-GENERATORS

Century Elec. Co., 1806 Pine St., St. Louis 3, Mo.
Crocker-Wheeler Div., Joshua Hendy Iron Wks., Ampere, N.J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hobart Bros. Co., 146 Hobart Square, Troy, O.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
Master Elec. Co., 126 Davis Ave., Dayton 1, O.
Star Elec. Motors Co., 200 Bloomfield Ave., Bloomfield, N.J.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

MOTOR BASES, BRACKETS & SUPPORTS (See BASES, MOTOR)

MOTOR PROTECTORS

Spencer Thermostat Div., Metals & Controls Corp., 34 Forest St., Attleboro, Mass.

MOTOR STARTERS (See STARTERS)

MOTORS, A.C., POLYPHASE

Louis Allis Co., 427 E. Stewart St., Milwaukee 7, Wis.
Allis-Chalmers Mfg., Co., Milwaukee 1, Wis.
Baldor Elec. Co., 4353 Duncan Ave., St. Louis 15, Mo.
Bello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.
Bodine Elec. Co., 2254 W. Ohio St., Chicago 12, Ill.
Burke Elec. Co., Erie, Pa.
Century Elec. Co., 1806 Pine St., St. Louis 3, Mo.
Cleveland Elec. Motor Co., 5213 Chester Ave., Cleveland 3, O.
Continental Elec. Co., Inc., 325 Ferry St., Newark 5, N.J.
Crocker-Wheeler Div., Joshua Hendy Iron Wks., Ampere, N.J.
Delco Products Div., Gen'l. Motors Corp., 329 E. 1st St., Dayton, O.
Diehl Mfg. Co., 1152 Finderne Ave., Somerville, N.J.
Eastern Air Devices, Inc., 130 Flatbush Ave., Brooklyn, N.Y.
Electric Boat Co., Ave. A & North St., Bayonne, N.J.
Electric Machinery Mfg. Co., 1338 Tyler St., N.E., Minneapolis 13, Minn.
Electro Machines, Inc., Cedarburg, Wis.
Elliott Co., Jeannette, Pa.
Emerson Elec. Mfg. Co., 8100 Florissant Ave., St. Louis 21, Mo.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hobart Bros. Co., 146 Hobart Square, Troy, O.
Howell Elec. Motors Co., 409 N. Roosevelt, Howell, Mich.
Ideal Elec. & Mfg. Co., Mansfield, O.
Imperial Elec. Co., 84 Ira St., Akron, O.
Kimble Elec., Div. of Miehle Printing Press & Mfg. Co., 2850 Mt. Pleasant St., Burlington, Ia.
Kingston-Conley Elec. Co., 86 Brook Ave., N. Plainfield, N.J.
King-Wyse, Inc., Archbold, O.
Leland Elec. Co., 1501 Webster St., Dayton 1, O.
Lima Elec. Motor Co., Findlay Rd., Lima, O.
Link-Belt Co., 2045 W. Hunting Park, Phila. 40, Pa.
Marathon Elec. Mfg. Corp., Wausau, Wis.
Marble-Card Elec. Co., Gladstone, Mich.
Master Elec. Co., 126 Davis Ave., Dayton 1, O.
Peerless Elec. Co., 2000 W. Market St., Warren, O.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua O.
Reliance Elec. & Engrg. Co., 1088 Ivanhoe Rd., Cleveland 10, O.
Reynolds Elec. Co., 2650 W. Congress. Chicago 12, Ill.
Robbins & Myers, Inc., Springfield, O.
Small Motors, Inc., 2068 Elston Ave., Chicago 14, Ill.
A. O. Smith Corp., 3533 N. 27th St., Milwaukee 1, Wis.
Star Elec. Motors Co., 200 Bloomfield Ave., Bloomfield, N.J.
Sterling Elec. Motors, Inc., 5401 Anaheim-Telegraph Rd., Los Angeles 22, Cal.
U. S. Elec'l. Motors, Inc., Los Angeles 54, Cal. & Milford, Ct.
Wagner Elec. Corp., 6400 Plymouth Ave., St. Louis 14, Mo.
Watson Flagg Machine Co., 845 E. 25th St., Paterson 3, N.J.
Westinghouse Elec. Corp., 4454 Genesee St., Buffalo 5, N.Y.

MOTORS, A.C., SINGLE PHASE

Baldor Elec. Co., 4353 Duncan Ave., St. Louis 15, Mo.
Bodine Elec. Co., 2254 W. Ohio St., Chicago 12, Ill.
Century Elec. Co., 1806 Pine St., St. Louis 3, Mo.
Delco Products Div., Gen'l. Motors Corp., 329 E. 1st St., Dayton, O.
Diehl Mfg. Co., 1152 Finderne Ave., Somerville, N.J.
Eastern Air Devices, Inc., 130 Flatbush Ave., Brooklyn, N.Y.
Electric Motor Corp., 1211 State St., Racine, Wis.
Electro Machines, Inc., Cedarburg, Wis.
Emerson Elec. Mfg. Co., 8100 Florissant Ave., St. Louis 21, Mo.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Fasco Industries, Inc., Union & Augusta Sts., Rochester 2, N.Y.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hobart Bros. Co., 46 Hobart Square, Troy, O.
Jack & Heintz Precision Industries, Inc., 17600 Broadway Cleveland 1, O.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
King-Wyse, Inc., Archbold, O.
Kingston-Conley Elec. Co., 86 Brook Ave., N. Plainfield, N.J.
Leland Elec. Co., 1501 Webster St., Dayton 1, O.
Lima Elec. Motor Co., Findlay Rd., Lima, O.
Marathon Elec. Mfg. Corp., Wausau, Wis.
Master Elec. Co., 126 Davis Ave., Dayton 1, O.
Peerless Elec. Co., 2000 W. Market St., Warren, O.
Piqua Machine & Mfg. Co., Young & Coolidge St., Piqua, O.
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
Robbins & Myers, Inc., Springfield, O.
Russell Elec. Co., 4501 S. Western Blvd., Chicago 9, Ill.
Small Motors, Inc., 2068 Elston Ave., Chicago 14, Ill.
A. O. Smith Corp., 3533 N. 27th St., Milwaukee 1, Wis.
Sterling Elec. Motors, Inc., 5401-Anaheim-Telegraph Rd., Los Angeles 22, Cal.
Victor Elec. Products, Inc., 2950 Roberston Rd., Cin'ti. 9, O.
Wagner Elec. Corp., 6400 Plymouth Ave., St. Louis 14, Mo.
Westinghouse Elec Corp., Lima, O.

MOTORS, CONTROL, INSTRUMENT, MINIATURE, etc.

Alliance Mfg. Co., 100 Lake Park Blvd., Alliance, O.
Barber-Colman Co., Rockford, Ill.
Bodine Elec. Co., 2254 W. Ohio St., Chicago 12, Ill.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
R. W. Cramer Co., P.O. Box 25, Centerbrook, Ct. *(p. 194)*
Diehl Mfg. Co., 1152 Finderne Ave., Somerville, N.J.
Eastern Air Devices, Inc., 130 Flatbush Ave., Brooklyn, N.Y.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Electric Motor Corp., 1211 State, Racine, Wis.
Fasco Industries, Inc., Union & Augusta Sts., Rochester 2, N.Y.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Master Elec. Co., 126 Davis Ave., Dayton 1, O.
Redmond Co., Inc., Owosso, Mich.
Russell Elec. Co., 4501 S. Western Blvd., Chicago 9, Ill.
Signal Elec. Mfg. Co., Menominee, Mich.
Small Motors, Inc., 2068 Elston Ave., Chicago 14, Ill.

MOTORS, D.C.

Louis Allis Co., 427 E. Stewart St., Milwaukee 7, Wis.
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Baldor Elec. Co., 4353 Duncan Ave., St. Louis 15, Mo.
Bello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.

Bodine Elec. Co., 2254 W. Ohio St., Chicago 12, Ill.
Burke Elec. Co., Erie, Pa.
Century Elec. Co., 1806 Pine St., St. Louis 3, Mo.
Continental Elec. Co., Inc., 325 Ferry St., Newark 5, N.J.
Crocker-Wheeler Div., Joshua Henry Iron Wks., Ampere, N.J.
Delco Products Div., Gen'l. Motors Corp., 329 E. 1st St., Dayton, O.
Diehl Mfg. Co., 1152 Finderne Ave., Somerville, N.J.
Eastern Air Devices, Inc., 130 Flatbush Ave., Brooklyn, N.Y.
Electric Boat Co., Ave. A & North St., Bayonne, N.J.
Elliott Co., Jeanette, Pa.
Emerson Elec. Mfg. Co., 8100 Florissant Ave., St. Louis 21, Mo.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Ideal Elec. & Mfg. Co., E. First St., Mansfield, O.
Imperial Elec. Co., 84 Ira St., Akron, O.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
Leland Elec. Co., 1501 Webster St., Dayton 1, O.
Link-Belt Co., 2045 W. Hunting Park, Phila. 40, Pa.
Marathon Elec. Mfg. Corp., Wausau, Wis.
Marble-Card Elec. Co., Gladstone, Mich.
Master Elec. Co., 126 Davis Ave., Dayton 1, O.
Peerless Elec Co., 2000 W. Market St., Warren, O.
Reliance Elec. & Engrg. Co., 1088 Ivanhoe Rd., Cleveland 10, O.
Robbins & Myers, Inc., Springfield, O.
Small Motors, Inc., 2068 Elston Ave., Chicago 14, Ill.
Star Elec. Motors Co., 200 Bloomfield Ave., Bloomfield, N.J.
U. S. Elec'l. Motors, Inc., Los Angeles 54, Cal. & Milford, Ct.
Wagner Elec. Corp., 6400 Plymouth Ave., St. Louis 14, Mo.
Westinghouse Elec. Corp., Lima, O.

MOTORS, DAMPER (See DAMPER MOTORS)

MOTORS, GEARHEAD

Louis Allis Co., 427 E. Stewart St., Milwaukee 7, Wis.
Bodine Elec. Co., 2554 W. Ohio St., Chicago 12, Ill.
Century Elec. Co., 1806 Pine St., St. Louis 3, Mo.
Cleveland Elec. Motor Co., 5213 Chester Ave., Cleveland 3, O.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Howell Elec. Motors Co., 409 N Roosevelt, Howell, Mich.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
Link-Belt Co., 2045 W Hunting Park, Phila. 40, Pa.
Master Elec. Co., 126 Davis Ave., Dayton 1, O.
Philadelphia Gear Wks., Inc., G St. & Erie Ave., Phila. 20, Pa.
Star Elec. Motors Co., 200 Bloomfield Ave., Bloomfield, N.J.
Sterling Elec. Motors, Inc., 5401 Anaheim-Telegraph Rd., Los Angeles 22, Cal.
Watson-Flagg Machine Co., 845 E. 25th St., Paterson 3, N.J.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

MOTORS FOR HERMETIC COMPRESSORS

Louis Allis Co., 427 E. Stewart St., Milwaukee 7, Wis.
Century Elec. Co., 1806 Pine St., St. Louis 3, Mo.
Delco Products Div., Gen'l. Motors Corp., 329 E. 1st St., Dayton, O.
Emerson Elec. Mfg. Co., 8100 Florissant Ave., St. Louis 21, Mo.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Westinghouse Elec. Corp., Lima, O.

MOTORS, HIGH FREQUENCY

Louis Allis Co., 427 E. Stewart St., Milwaukee 7, Wis.
Eastern Air Devices, Inc., 130 Flatbush Ave., Brooklyn N.Y.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Leland Elec. Co., 1501 Webster St., Dayton 1, O.
Onsrud Machine Wks., Inc., 3900 Palmer St., Chicago 47, Ill.

MOTORS, SPECIAL

Louis Allis Co., 427 E. Stewart St., Milwaukee 7, Wis.
Baldor Elec. Co., 4353 Duncan Ave., St. Louis 15, Mo.
Bodine Elec. Co., 2254 W. Ohio St., Chicago 12, Ill.
Burke Elec. Co., Erie, Pa.
Cleveland Elec. Motor Co., 5213 Chester Ave., Cleveland 3, O.
Continental Elec. Co., Inc., 325 Ferry St., Newark 5, N.J.
Diehl Mfg. Co., 1152 Finderne Ave., Somerville, N.J.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Emerson Elec. Mfg. Co., 8100 Florissant Ave., St. Louis 21, Mo.
Forbes & Myers, 173 Union St., Worcester, Mass.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hoover Elec. Co., 2100 Stoner Ave., W. Los Angeles 25, Cal.
Howell Elec. Motors Co., 409 N. Roosevelt, Howell, Mich.
Ideal Elec. & Mfg. Co., E. First St., Mansfield, O.
Imperial Elec. Co., 84 Ira St., Akron, O.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
King-Wyse, Inc., Archbold, O.
Leland Elec. Co., 1501 Webster St., Dayton 1, O.
Lima Elec. Motor Co., Findlay Rd., Lima, O.
Marathon Elec. Mfg. Corp., Wausau, Wis.
Marble-Card Elec. Co., Gladstone, Mich.
Master Elec. Co., 126 Davis Ave., Dayton 1, O.
Moore Co., 544 Westport Rd., Kansas City 2, Mo. (Slow speed)
Peerless Elec. Co., 2000 W. Market St., Warren, O.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
Robbins & Myers, Inc., Springfield, O.
Russell Elec. Co., 4501 S. Western Blvd., Chicago 9, Ill.
Signal Elec. Mfg. Co., Menominee, Mich.
Small Motors, Inc., 2068 Elston Ave., Chicago 14, Ill.
A. O. Smith Corp., 3533 N. 27th St., Milwaukee 1, Wis.
Star Elec. Motors Co., 200 Bloomfield Ave., Bloomfield, N.J.
Wagner Elec. Corp., 6400 Plymouth Ave., St. Louis 14, Mo.
Westinghouse Elec. Corp., 4454 Genesee St., Buffalo 5, N.Y.

MOTORS, UNIVERSAL

Bodine Elec. Co., 2254 W. Ohio St., Chicago 12, Ill.
Diehl Mfg. Co., 1152 Finderne Ave., Somerville, N.J.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Signal Elec. Mfg. Co., Menominee, Mich.
Small Motors, Inc., 2068 Elston Ave., Chicago 14, Ill.
Westinghouse Elec. Corp., Lima, O.

MOULDINGS

Brasco Mfg. Co., Harvey, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
Greene Mfg. Co., Inc., 1028 Douglas Ave., Racine, Wis.
John Lees Div., Serrick Corp., 1300 Batavia, Muncie, Ind.
Mack Molding Co., Ryerson Ave., Wayne, N.J.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich. (Plastic)
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber & Plastic)
R. D. Werner Co., Inc. 295-5th Ave., N.Y.C. 16

MOUNTINGS, VIBRATION ABSORBING (See VIBRATION ABSORBING BASES)

MUFFLERS, PIPE LINE

Drico Industrial Corp., 29 Broadway, N.Y.C. 6
Alexander-Tagg Industries, Inc., Jacksonville Rd. & Summit Ave., Hatboro, Pa.
Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*

NAILS

All-metal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Aluminum Co. of America, Pittsburgh 19, Pa.
American Rolling Mill Co., Middletown, O. (Stainless Steel)
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Armco Steel Corp., Middletown, O.
Atlantic Steel Corp., P.O. Box 1714, Atlanta, Ga.
Bethlehem Steel Co., Bethlehem, Pa.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Il
International Nickel Co., 67 Wall St., N.Y.C. 5 (Nickel Alloy)
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Townsend Co., 205 River Rd., New Brighton, Pa.
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp., 500-5th Ave., N.Y.C. 18
Alan Wood Steel Co., Steel Mill Rd., Conshohocken, Pa. (Cut)
Youngstown Sheet & Tube Co., Youngstown, O.

NAME PLATES (See also TRIM)

Acme Metal Etching Co., Inc., 4857 St. Aubin, Detroit 7, Mich.
Acromark Co., 5 Morrell St., Elizabeth 5, N.J.
American Emblem Co., Inc., P.O. Box 116-H, Utica 1, N.Y.
Anderson & Sons, Inc., N. Elm St., Westfield, Mass.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Chandler Co., 1407 Park St., Hartford 6, Ct.
Croname, Inc., 3701 N. Ravenswood, Chicago 13, Ill.
Dearborn Glass Co., 2414 W. 21st St., Chicago 8, Ill.
Electro-Chemical Engraving Co., Inc., 1100 Brook Ave., N.Y.C.
Fox Co., Fox Lane, Cin'ti. 23, O.
L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Grand Rapids Brass Co., 160 Scribner Ave., N.W., Grand Rapids 1, Mich.
Hoosier Cardinal Corp., 601 W. Eichel Ave., Evansville 7, Ind.
Mack Molding Co., Ryerson Ave., Wayne, N.J.
James H. Mathews & Co., 3948 Forbes St., Pittsburgh 13, Pa.
Geo. J. Mayer Co., 15 N. Pennsylvania St., Indpls. 9, Ind.
A.B. Murray, Inc., 604 Green Lane, Elizabeth, N.J.
Newman Bros., Inc., 666 W. 4th St., Cin'ti. 3, O.
Northern Engraving & Mfg. Co., 4th & Vine Sts., La Crosse, Wis.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Reynolds Metals Co., 2000 S. 9th St., Kouisville 1, Ky.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Sneath Glass Co., Hartford City, Ind.
Standard Molding Corp., 1517 E. 3rd St., Dayton 1, O.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Stanley Works, 195 Lake St., New Britain, Ct.
Amos Thompson Corp., Edinburg, Ind.

NEEDLE VALVE ASSEMBLIES

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Ashton Valve Co., 161-1st St., Cambridge 42, Mass.
Jerguson Gage & Valve, 87 Fellsway, Somervile, Mass.
Mayson Mfg. Co., Inc., 4332 Horatio St., Detroit 10, Mich.

NEEDLES, VALVE

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Illl.
Mayson Mfg. Co., Inc., 4332 Horatio St., Detroit 10, Mich.

NEGATIVE TEMPERATURE COEFFICIENT MATERIAL

Keystone Carbon Co., Inc., 1935 State St., St. Marys, Pa.

NETTING, WIRE (See MESH, METAL)

NICKEL (See also mill forms, i.e., ROD; also SHEET, etc.)

Haynes Stellite Co., Unit. of Union Carbide & Carbon Corp., Kokomo, Ind.
International Nickel Co., 67 Wall St., N.Y.C. 5

NIPPLES, PIPE (See FITTINGS)

NITROGEN

Linde Air Products Co., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17

NOSES, SEAL

Chicago Seal Co., 232 S. Hoyne Ave., Chicago 20, Ill.
Federal-Mogul Corp., Shoemaker & Lillibridge Sts., Detroit 13, Mich.

NOZZLES

April Showers Co., 4126-8th St., N.W., Washington 11, D.C. *(p. 175)*
Bahnson Co., 1000 S. Marshall St., Winston-Salem, N.C.
Baliofet Dies & Nozzle Co., Inc., 6825 Adams St., Guttenberg, N.J.
Binks Mfg. Co., 3114 Carroll Ave., Chicago 12, Ill.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
Clarage Fan Co., Porter St., Kalamazoo 16, Mich.
Delavan Mfg. Co., 3009-6th Ave., Des Moines 13, Ia.
Diester Concentrator, 901 Glasgow Ave., Ft. Wayne, Ind.
Eclipse Air Brush Co., Inc., 381 Park Ave., Newark 7, N.J.
Electric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
Fluor Corp., Ltd., 2500 S. Atlantic Blvd., Los Angeles 22, Cal.
Grinnell Co., 260 W. Exchange St., Providence 1, R.I.
Link-Belt Co., 300 Pershing Rd., Chicago 9, Ill.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
Marley Co., Inc., 3001 Fairfax Rd., Kansas City 15, Kan. *(p. 75)*
Jos. A. Martocello & Co., 229 N. 14th St., Phila. 7, Pa. *(p. 147)*
Monarch Mfg. Wks., Inc., Salmon & Westmorland Sts., Phila. 34, Pa.
D. J. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Parks-Cramer Co., Box 444, Fitchburg, Mass.
Phillips Cooling Tower Co., Inc., 114 Liberty St., N.Y.C. 6
J. F. Pritchard & Co., 2200 Fidelity Bldg., Kansas City 6, Mo. *(p. 73)*
Rhode Island Humidifier & Ventilating Co., 99 Chauncey St., Boston 11, Mass.
Spray Engrg. Co., 114 Central St., Somerville 45, Mass.
Spraying Systems Co., 3201 Randolph St., Bellwood, Chicago, Ill.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Supreme Elec. Products Co., 194 Vassar St., Rochester 7, N.Y.
Thermal Industries, P.O. Box 725, Indio, Cal.
Water Cooling Corp., 71 Nassau St., N.Y.C. 7
Water Cooling Equip. Corp., Afton Sta., St. Louis 23, Mo.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.

NUTS

Allmeter Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Bethlehem Steel Co., Bethlehem, Pa.
Boots Aircraft Nut Corp., 50 John St., Stamford, Ct.

(Continued)

NUTS (Continued)

Boss Nut & Bolt Co., 3403 W. 47th St., Chicago, Ill.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago Screw Co , 2701 Washington Blvd., Bellwoood, Ill.
Clark Bros. Bolt Co., Milldale, Ct.
Columbus Bolt Wks. Co., 291 Marconi Blvd., Columbus 16, O.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Wm. R. Haskell Mfg. Co., 24 Commerce St., Pawtucket, R.I.
Haynes Stellite Co., Unit. of Union Carbide & Carbon Corp., Kokomo, Ind.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Republic Steel Corp. Republic Bldg., Cleveland 1, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Stover Lock Nut & Machinery Corp., Bushkill Drive, Easton, Pa.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

NUTS, LOCK

Allmetal Screw Products Co., 33 Greene St., N.Y.C. 13
Boss Nut & Bolt Co., 340 W. 47th St., Chicago, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Clark Bros. Bolt Co., Milldale, Ct.
Elastic Stop Nut Corp. of America, 2330 Vauxhall Rd., Union, N.J.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Laminated Shim Co., Inc., Union St., Glenbrook, Ct.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Prestole Corp., 1345 Miami St., Toledo, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Stover Lock Nut & Machinery Corp., Bushkill Drive, Easton, Pa.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Thompson-Bremer & Co., 1640 W. Hubbard St., Chicago 22, Ill.
Tinnerman Products, Inc., 2038 Fulton Rd., Cleveland 13, O.
Townsend Co., 205 River Rd., New Brighton, Pa.
Walworth Co., 60 E. 42nd St., N.Y.C. 17

NUTS, MACHINE

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Bethlehem Steel Co., Bethlehem, Pa.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
Corbin Screw Corp., New Britain, Ct.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Wm. H. Haskell Mfg. Co., 24 Commerce St., Pawtucket, R.I.
Laminated Shim Co., Inc., Union St., Glenbrook, Ct.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

NUTS, SPEED (See FASTENERS)

NUTS, STOVE

Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
Corbin Screw Corp., New Britain, Ct.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Republic Steel Corp, .Republic Bldg., Cleveland 1, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

NUTS, WELD

Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Ohio Nut & Bolt Co., 600 Front St., Berea, O.
Penn Engrg. & Mfg. Corp., 305 Main St., Doylestown, Pa.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Prestole Corp., 1345 Miami St., Toledo, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

ODOR ELIMINATION UNITS & SYSTEMS (See AIR PURIFICATION EQUIPMENT)

OIL COOLERS & OIL COOLING SYSTEMS (See also COOLANT COOLERS)

Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 *(p. 122)*
Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
Reliance Refrigerating Machine Co., 3401 N. Kedzie Ave., Chicago 18, Ill.
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Ross Heater & Mfg. Co., Div. of American Radiator & Standard Sanitary Corp., Buffalo 13, N.Y.
Schutte & Koerting Co., 12th & Thompson Sts., Phila. 22, Pa.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
Young Radiator Co., Racine, Wis. *(p. 9)*

OIL ENGINES (See ENGINES, DIESEL)

OIL SEPARATORS

Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*
Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. [illegible])*
King-Zeero Co., 1447 Montrose Ave., Chicago 13, Ill. *(p. 149)*
Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
Rex Engineering & Sales Co., Box 5141, Oklahoma City, Okla.

rong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
emprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. (p. 86)
abash Mfg. Co., 2300 S. Western Ave., Chicago 8, Ill. (Small)
orthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
right-Austin Co., 315 W. Woodbridge St., Detroit 26, Mich.
ork Corp., York, Pa. (p. 119)

ILERS & OILING SYSTEMS (See LUBRICATORS)

ILS, LUBRICATING

nsul Chemical Co., Marinette, Wis. (p. 167)
tlantic Refining Co., 260 S. Broad St., Phila., Pa.
ities Service Oil Co. (Del.), 919 N. Michigan Ave., Chicago, Ill.
ities Service Oil Co. (Pa.), 60 Wall Tower, N.Y.C. 5
sso Standard Oil Co., 15 W. 51st St., N.Y.C. 19
iske Bros. Refining Co., 129 Lockwood St., Newark 5, N.J.
ulf Oil Corp., Gulf Bldg., Pittsburgh, Pa.
. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
eystone Lubricating Co., 21st & Lippincott Sts., Phila. 32, Pa.
ubriplate Div., Fiske Bros. Refining Co., 129 Lockwood St., Newark, N.J.
facmillan Petroleum Corp., 530 W. 6th St., Los Angeles 14, Cal.
ew York & New Jersey Lubricant Co., 292 Madison Ave., N.Y.C. 17
hell Oil Co., Inc., 50 W. 50th St., N.Y.C. 20
inclair Refining Co., 630-5th Ave., N.Y.C. 20
ocony-Vacuum Oil Co., 26 B'way, N.Y.C. 4
. Sonneborn Sons, Inc., 88 Lexington Ave., N.Y C. 16
tandard Oil Co. of California, 225 Bush St., San Francisco 20, Cal.
). A. Stuart Oil Co., Ltd., 2727 S. Troy St., Chicago 23, Ill.

Sun Cil Co., 1608 Walnut St., Phila. 3, Pa.
Swan-Finch Oil Corp., 30 Rockefeller Plaza, N.Y.C. 3
Texas Co., 135 E. 42nd St., N.Y.C. 17
Tide Water Associated Oil Co., 17 Battery Place, N.Y.C. 4
Valvoline Oil Co., 534 E. 5th St., Cin'ti 2, O.
Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)

OZONE EQUIPMENT

Electroaire Corp., 41-38-37th St., Long Island City 1, N.Y.
Norwood Filtration Co., Northampton, Mass.
Welsbach Corp., 1500 Walnut St., Phila. 2, Pa.

PACKING, SHAFT, VALVE, etc.

American Metallic Packing Co., 3621 Mexico St., Pittsburgh 12, Pa.
Anchor Packing Co., 401 N. Broad St., Phila. 8, Pa.

(Continued)

PACKING (Continued)

Belmont Packing & Rubber Co., Butler & Sepviva Sts., Phila. 7, Pa.
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Chicago Belting Co., 113 N. Green St., Chicago 7, Ill.
Chicago Rawhide Mfg. Co., 1306 Elston Ave., Chicago 22, Ill.
Continental Rubber Wks., 2000 Liberty St., Erie, Pa.
C. Lee Cook Mfg. Co., 916 S. 8th St., Louisville 3, Ky.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
Crane Packing Co., 1800 Cuyler Ave., Chicago 13, Ill.
Darcoid Co., Inc., 145-6th Ave., N.Y.C. 13
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del. (Plastic)
Durabla Mfg. Co., 114 Liberty St., N.Y.C. 6
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
Endura Mfg. Corp., 45 N. 4th St., Quakertown, Pa.
Ernst Water Column & Gauge Co., 250 S. Livingston Ave., Livingston, N.J.
Felt Products Mfg Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Fisher Leather Belting Co., Inc., 325 N. 3rd St., Phila. 6, Pa.
France Packing Co., Tacony, Phila. 35, Pa.
Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Harper Packing Co., Inc., 312 Patterson St., Chester, Pa.
Hollow Center Packing Co., 6523 Euclid Ave., Cleveland 3, O.
E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago 5, Ill.
National Carbon Co., Inc., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
National Motor Bearing Co., Inc., Redwood City, Cal.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Rains Wood Metal Packings, 904 W. B'way, Spokane 5, Wash.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
J. E. Rhoads & Sons, 35 N. 6th St., Phila. 6, Pa.
Rhopac, Inc., 168 N. Clinton St., Chicago 6, Ill.
Rodpak Mfg. Co., 1315 Natoma St., San Francisco 3, Cal.
Chas. A. Schieren Co., 30 Ferry St., N.Y.C. 7
U. S. Graphite Co., Saginaw, Mich.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Victor Mfg. & Gasket Co., 5750 Roosevelt Rd., Chicago 90, Ill.

PACKING, SHEET (See GASKET MATERIAL)

PAINT (See FINISHES or particular type following)

PAINT, ASPHALT

American Bitumuls Co., 200 Bush St., San Francisco 4, Cal.
Arco Co., 7301 Bessemer Ave., Cleveland 4, O.
Calbar Paint & Varnish Co., 2612 N. Martha St., Phila. 25, Pa.
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.
Esso Standard Oil Co., 15 W. 51st St., N.Y.C. 19
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.
Grand Rapids Varnish Corp., 1350 Steele Ave., S.W., Grand Rapids 2, Mich.
Alfred Hague & Co., 227-34th St., Brooklyn 32, N.Y.
Hooker Glass & Paint Mfg. Co., 659 W. Washington Blvd., Chicago, Ill.
A. C. Horn Co., Inc., 43-36-10th St., Long Island City, N.Y.
Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N.J.
Midland Paint & Varnish Co., 3801 E. 91st St., Cleveland 5, O.
Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10 Mo.
Quigley Co., Inc., 527-5th Ave., N.Y.C. 17
Randolph Products Co., Carlstadt, N.J. *(p. 101*
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Rutland Fire Clay Co., Curtis Ave., Rutland, Vt.
Sherwin-Williams Co., 101 Prospect Ave., N.W., Cleveland, O.
Stencal Asphalt & Bitumuls Co., 200 Bush St., San Francisco 22, Cal.
Steelcote Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo
U. S. Gutta Percha Paint Co., Dudley & Eddy Sts., Providence 1, R.I.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.
Western Chemical Co., 713 Washington St., Kansas City 6, Mo.
J. C. Whitlam Mfg. Co., Wadsworth, O.
Wilbur-Williams Co., 43 Leon St., Boston, Mass.
Zapon Div., Atlas Powder Co., Stamford, Ct.

PAINT, CORROSION RESISTING

Amercoat Div., American Pipe & Construction Co., 480[illegible] Firestone Blvd., Southgate, Cal.
American Chemical Paint Co., Ambler, Pa.
American Pipe & Construction Co., Box 3428 Terminal Annex P.O., Los Angeles, Cal.
Arco Co., 7301 Bessemer Ave., Cleveland 4, O.
Calbar Paint & Varnish Co., 2612 N. Martha St., Phila 25, Pa.
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago, Ill. *(p. 50*
Dennis Chemical Co., 2701 Papin St., St. Louis 3, Mo.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98 Del.
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
Ernecke & Salmstein Co., 1611 N. Sheffield Ave., Chicago 14, Ill.
Esso Standard Oil Co., 15 W. 51st St., N.Y.C. 19
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa
Grand Rapids Varnish Corp., 1350 Steele Ave., S.W. Grand Rapids 2, Mich.
Alfred Hague & Co., 227-34th St., Brooklyn 32, N.Y.
A. C. Horn Co., Inc., 43-36-10th St., Long Island City N.Y.
Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N.J
Interchemical Corp., 57 State St., Newark, N.J.
Jones-Dabney Co., Div. of Devoe & Raynolds, 1481 S 11th St., Louisville 8, Ky.
Maas & Waldstein Co., 438 Riverside Ave., Newark 4 N.J.
Master Mechanics Co., Freeman Rd., Cleveland 13, O.
Midland Paint & Varnish Co., 3801 E. 91st St., Cleveland 5, O.
National Lead Co., 111 Broadway, N.Y.C. 6
Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10 Mo.
Quigley Co., Inc., 527-5th Ave., N.Y.C. 17
Randolph Products Co., Carlstadt, N.J. *(p. 101*
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Sherwin-Williams Co., 101 Prospect Ave., N.W., Cleveland, O.
Steelcote Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo.
United Chromium, Inc., 51 E. 42nd St., N.Y.C. 17
U. S. Gutta Percha Paint Co., Dudley & Eddy Sts., Providence 1, R.I.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N J.
Wailes Dove-Hermiston Corp., 448 South Ave., Westfield N.J.
J. C. Whitlam Mfg. Co., Wadsworth, O.
Wilbur-Williams Co., 43 Leon St., Boston, Mass.
Zapon Div., Atlas Powder Co., Stamford, Ct.

PAINT, HEAT RESISTING

Amercoat Div., American Pipe Construction Co., 480[illegible] Firestone Blvd., Southgate, Cal.
American Chemical Paint Co., Ambler, Pa.
Arco Co., 7301 Bessemer Ave., Cleveland 4, O.
Calbar Paint & Varnish Co., 2612 W. Martha St., Phila 25, Pa.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa
Grand Rapids Varnish Corp., 1350 Steele Ave., S.W. Grand Rapids 2, Mich.

A. C. Horn Co., Inc., 43-36-10th St., Long Island City, N.Y.
Inertol Co., Inc., 470 Frelinghuysen Ave., Newark 5, N.J.
Jones-Dabney Co., Div. of Devoe-Raynolds, 1481 S. 11th St., Louisville 8, Ky.
Maas & Waldstein Co., 438 Riverside Ave., Newark 4, N.J.
Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Quigley Co., Inc., 527-5th Ave., N.Y.C. 17
Randolph Products Co., Carlstadt, N.J. *(p. 101)*
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Sherwin-Williams Co., 101 Prospect Ave., N.W., Cleveland, O.
Steelcoate Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo.
U. S. Gutta Percha Paint Co., Dudley & Eddy Sts., Providence 1, R.I.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.
Wailes Dove-Hermiston Corp., 448 South Ave., Westfield, N.J.
Western Chemical Co., 713 Washington St., Kansas City 6, Mo.
J. C. Whitlam Mfg., Wadsworth, O.
Wilbur-Williams Co., 43 Leon St., Boston, Mass
Zapon Div., Atlas Powder Co., Stamford, Ct.

PAINT, METALLIC

Aetna Plywood & Veneer Co., 1799 Elston Ave., Chicago 22, Ill.
Amercoat Div., American Pipe & Construction Co., 4809 Firestone Blvd., Southgate, Cal.
Brooklyn Varnish Mfg. Co., Inc., 50 Jay St., Brooklyn 1, N.Y.
Calbar Paint & Varnish Co., 2612 N. Martha St, Phila. 25, Pa.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.
Grand Rapids Varnish Corp., 1350 Steele Ave., S.W., Grand Rapids 2, Mich.
Alfred Hague & Co., 227-34th St., Brooklyn 32, N.Y.
Hooker Glass & Paint Mfg. Co., 659 W. Washington Blvd., Chicago, Ill.
A. C. Horn Co., Inc., 43-36-10th St., Long Island City, N.Y.
Interchemical Corp., 57 State St., Newark, N.J.
Jones-Dabney Co., Div. of Devoe & Raynolds, 1481 S. 11th St., Louisville 8, Ky.
Maas & Waldstein Co., 438 Riverside Ave., Newark 4, N.J.
Midland Paint & Varnish Co., 3801 E. 91st St., Cleveland 5, O.
Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Quigley Co., Inc., 527-5th Ave., N.Y.C. 17
Randolph Products Co., Carlstadt, N.J. *(p. 101)*
Rutland Fire Clay Co., Curtis Ave., Rutland, Vt.
Sherwin-Williams Co., 101 Prospect Ave., N.W., Cleveland, O.
Smooth-On Mfg. Co., 572 Communipaw Ave., Jersey City 4, N.J.
Steelcote Mfg. Co., 3418 Gratiot Ave., St. Louis 3, Mo.
U. S. Gutta Percha Paint Co., Dudley & Eddy Sts., Providence 1, R.I.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.
Western Chemical Co., 713 Washington St., Kansas City 6, Mo.
J. C. Whitlam Mfg. Co., Wadsworth, O.
Wilbur-Williams Co., 43 Leon St., Boston, Mass.
Zapon Div., Atlas Powder Co., Stamford, Ct.

PANELS, CABINET

Acklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*
Falstrom Co., 13 Falstrom Court, Passaic, N. J.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*

PANELS, INSTRUMENT (See INSTRUMENT PANELS)

PAPER, ASBESTOS

Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17 *(p. 135)*
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Victor Mfg. & Gasket Co., 5750 Roosevelt Rd., Chicago 90, Ill.

PAPER, BUILDING

Aetna Plywood & Veneer Co., 1799 Elston Ave., Chicago 21, Ill.
Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17
Angier Corp., Framingham, Mass.
Atlas Asbestos Co., Ltd., 110 McGill St., Montreal 1, Quebec, Canada
Philip Carey Mfg. Co., Lockland, Cin'ti. 15, O.
Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Lehon Co., 4425 S. Oakley Ave., Chicago 9, Ill.
Pacific States Felt & Mfg. Co., Inc., 843 Howard St., San Francisco 3, Cal.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10, Mo.
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Grant Wilson, Inc., 316 S. La Salle St., Chicago 4, Ill.

PAPER & FABRIC, COATED OR IMPREGNATED (See also FIBRE)

Formica Co., 4613 Spring Grove Ave., Cin'ti 32, O.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10, Mo.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Wilmington Fibre Specialty Co., P.O. Drawer 1028, Wilmington 99, Del.
Wolverine Fabricating & Mfg. Co., Inc., Princess St. & M.C.R.R., Inkster, Mich.

PAPER PRODUCTS, MOLDED

Panelyte Div., St. Regis Paper Co., 230 Park Ave., N.Y.C. 17

PARTS, HARDENED & GROUND

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
McQuay-Norris Mfg. Co., 2320 Marconi Ave., St. Louis 10, Mo.

PASSING DOORS (See COLD STORAGE DOORS)

PERFORATED METALS (See METAL, PERFORATED)

PHOSPHOR BRONZE

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Bristol Brass Corp., Bristol, Ct.
Chase Brass & Copper Co., 236 Grand St., Waterbury, Ct.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. *(p. 197)*
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Western Brass Mills, Div. of Olin Industries, Inc., E. Alton 17, Ill.

PHOTOGRAPHIC COOLING EQUIPMENT (See also WATER COOLERS)

Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 *(p. 122)*
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*

PILLOW BLOCKS (See BEARINGS)

PILOT LIGHTS

Drake Mfg. Co., 1709 W. Hubbard St., Chicago 22, Ill.
Hart Mfg. Co., 110 Bartholomew Ave., Hartford 1, Ct.

PINS, DOWEL

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
(Continued)

PINS, DOWEL (Continued)

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Bethlehem Steel Co., Bethlehem, Pa.
Holo-Krome Screw Corp., 25 Brook St., Hartford 10, Ct.
Standard Pressed Steel Co., Jenkintown, Pa.
Standard Steel Specialty Co., Beaver Falls, Pa.
Townsend Co., New Brighton, Pa.

PINS, SPECIAL

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Standard Steel Specialty Co., Beaver Falls, Pa.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

PIPE (See particular type following; also TUBES & TUBING)

PIPE, COPPER

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Lewin-Mathes Co., 1111 Chouetau. St. Louis 2, Mo.
Mueller Brass Co., Port Huron, Mich.
National Copper & Smelting Co., 1862 E. 123rd St., Cleveland 6, O.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

PIPE, CORROSION RESISTING

Allmetal Screw Products Co., 33 Greene St., N.Y.C. 13
American Brass Co., Waterbury 88, Ct. *(p. 199)*
Babcock & Wilcox Tube Co., Beaver Falls, Pa.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Duriron Co., Inc., Dayton 1, O.
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Carbon Co., Inc., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
National Tube Co., U. S. Steel Corp., Subsidiary, P.O. Box 266, Pittsburgh, Pa.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

PIPE, FURNACE & STOVE

Excelsior Steel Furnace Co., 118 S. Clinton St., Chicago 6, Ill.
Henry Furnace Co., Medina, O.
L. J. Mueller Furnace Co., 2005 W. Oklahoma Ave., Milwaukee 7, Wis.
National Gypsum Co., 325 Delaware Ave., Buffalo 2, N.Y.
Nebel Mfg. Co., 2366 Woodhill Rd., Cleveland 20, O.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
U. S. Register Co., 344 E. Burnham St., Battle Creek, Mich.
Wheeling Corrugating Co., Wheeling, W. Va.
Wheeling Steel Corp., Wheeling, W. Va.

PIPE, HARD RUBBER & PLASTIC

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Haveg Corp., Marshallton, Del.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Luzerne Rubber Co., Trenton 9, N.J.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

PIPE, SEAMLESS

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Babcock & Wilcox Tube Co., Beaver Falls, Pa.
Bethlehem Steel Co., Bethlehem, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
National Copper & Smelting Co., 1862 E. 123rd St., Cleveland 6, O.
National Tube Co., U. S. Steel Corp. Subsidiary, P.O. Box 266, Pittsburgh, Pa.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge Sts., Etna P.O., Pittsburgh 23, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Joseph T. Ryerson & Son Inc., 16th & Rockwell Sts., Chicago, Ill.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

PIPE, STEEL

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
W. R. Ames Co., 150 Hooper St., San Francisco 7, Cal.
Armco Drainage & Metal Products, Inc., Middletown, O.
Bethlehem Steel Co., Bethlehem, Pa.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
Central Iron & Steel Co., Harrisburg, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Laclede Stee Co., Arcade Bldg., St. Louis 1, Mo
Lehigh Fan & Blower Co., Div. of Heilman Boiler Wks. Inc. 128 Linden St., Allentown, Pa.
National Tube Co., U. S. Steel Corp., Subsidiary, P.O Box 266, Pittsburgh, Pa.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa. (Steel & Stainless)
Pittsburgh Tube Co., 323-4th Ave., Pittsburgh 22, Pa.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Taylor Forge & Pipe Wks., P.O. Box 485, Chicago 90, Ill.
Wheeling Steel Corp., Wheeling, W. Va.

PIPE, WROUGHT IRON

A. M. Byers Co., Clark Bldg., Pittsburgh 22, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Taylor Forge & Pipe Wks., P.O. Box 485, Chicago 90, Ill.

PIPE CLAMPS & HANGERS (See CLAMPS & HANGERS)

PIPE COILS, BENDS & BENDING (See also RETURN BENDS)

Acme Equip. Co., 205 E. B'way, Muskogee, Okla.
Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 21[illegible])*
Baker Refrigeration Corp., S. Windham, Me. *(p. [illegible])*
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus. O.
Carrier Corp., 302 S. Geddes St., Syracuse 1. N.Y. *(p. 45)*

Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago Nipple Mfg. Co., 1614 S. Laramie Ave., Chicago 50, Ill.
Cleveland Coppersmithing Wks., 5500 Stone Ave., Cleveland 2, O.
James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Dersch, Gesswein & Nevert, 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 23, N.Y. *(p. 56)*
Ellsworth Pipe & Supply Co., 513 W. Traser St., Milwaukee 3, Wis.
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Frick Co., Waynesboro, Pa. *(p. 44)*
General Refrigeration Div., Yates-American Machine Co., Beloit, Wis. *(p. 58)*
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. *(p. 204)*
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey City 7, N.J.
C. F. Moores Co., Inc., 1123 Ivy Hill Rd., Wyndmoor Phila. 18, Pa.
Mueller Brass Co., Port Huron, Mich. (Copper)
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N. J.
National Pipe Bending Co., 110 River St., New Haven 13, Ct.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.
Parks-Cramer Co., Box 444, Fitchburg, Mass.
R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Reliance Refrigerating Machine Co., 3401 N. Kedzie Ave., Chicago 18, Ill.
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Reynolds Mfg. Co., Inc., Springfield, Mo.
Roessing Mfg. Co., Sharpsburg Sta., Pittsburgh, Pa.
Shaw-Kendall Engrg. Co., 120 S. Superior St., Toledo 4, O.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa *(p. 119)*

PIPE COVERING (See INSULATION)

PISTONS

Frick Co., Waynesboro, Pa. *(p. 44)*
McQuay-Norris Mfg. Co., 2320 Marconi Ave., St. Louis 10, Mo.
Vilter Mfg. Co., 224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*

PISTON PINS

Frick Co., Waynesboro, Pa. *(p. 44)*
McQuay-Norris Mfg. Co., 2320 Marconi Ave., St. Louis 10, Mo.
Saginaw Malleable Iron Div., Gen'l. Motors Corp., Saginaw, Mich.

PISTON RINGS

American Hammered Piston Ring, Bush & Hamburg St., Baltimore, Md.
American Metallic Packing Co., 3621 Mexico St., Pittsburgh 12, Pa.
Burd Piston Ring Co., 10th & 23rd Ave., Rockford, Ill.
C. Lee Cook Mfg. Co., 916 S. 8th St., Louisville 3, Ky.
McQuay-Norris Mfg. Co., 2320 Marconi Ave., St. Louis 10, Mo.
Perfect Circle Co., 552 S. Washington, Hagerstown, Ind.
Saginaw Malleable Iron Div., Gen'l. Motors Corp., Saginaw, Mich.
Sealed Power Corp., 500 Sanford St., Muskegon 61, Mich.
Superior Piston Ring Co., 321 S. Cicero Ave., Chicago 44, Ill.
Wilkening Mfg. Co., 2000 S. 71st St., Phila. 42, Pa.

PLASTER, INSULATING (See INSULATI G PLASTER & CONCRETE)

PLASTIC MOLDING COMPOUNDS & PLASTICIZERS

Bakelite Corp., 60 E. 42nd St., N.Y.C. 17
Carbide & Carbon Chemicals Corp., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Celanese Plastics Corp., 180 Madison Ave., N.Y.C. 16
Chemaco Corp., Berkeley Heights, N.J.
Dennis Chemical Co., 2701 Papin St., St. Louis 3, Mo.
Dow Chemical Co., Midland, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Durez Plastics & Chemicals, Inc., 123 Walck Rd., N. Tonawanda, N.Y.
Esso Standard Oil Co., 15 W. 51st St., N.Y.C. 19
General Elec. Co., Plastics Div., 1 Plastic Ave., Pittsfield, Mass.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Haveg Corp., Marshallton, Del.
Monsanto Chemical Co., Plastics Div., 600 Monsanto Ave., Springfield 2, Mass.
Plaskon Div., Libbey, Owens, Ford Glass Co., 2112 Sylvan Ave., Toledo 6, O.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Rohm & Haas Co., 222 W. Washington Sq., Phila. 6, Pa.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Tennessee-Eastman Corp., 10 E. 40th St., N.Y.C. 16
Amos Thompson Corp., Edinburg, Ind.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

PLASTIC SHEETS, RODS & TUBES

Aetna Plywood & Veneer Co., 1799 Elston Ave., Chicago 22, Ill.
Celanese Plastics Corp., 180 Madison Ave., N.Y.C. 16
Dow Chemical Co., Midland, Mich.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Formica Co., 4613 Spring Grove Ave., Cin'ti 32, O.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Hudson Products Co., Inc., 4400 St. Aubin, Detroit 7 Mich.
Mack Molding Co., Ryerson Ave., Wayne, N.J.
Monsanto Chemical Co., Plastics Div., 600 Monsanto Ave., Springfield 2, Mass.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10, Mo.
Sandee Mfg. Co., 5050 W. Foster Ave., Chicago 30, Ill.
Technical Ply-Woods, 228 N. La Salle St., Chicago 1, Ill.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y C. 20
Wilmington Fiber Specialty Co., P.O. Drawer 1028, Wilmington 99, Del.

PLATE, ALLOY

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Bethlehem Steel Co., Bethlehem, Pa.
Haynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky. (Aluminum)
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.

PLATE, STEEL

Bethlehem Steel Co., Bethlehem, Pa.
Central Iron & Steel Co., Harrisburg, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Lukens Steel Co., Coatesville, Pa.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Wheeling Steel Corp., Wheeling, W. Va.
Youngstown Sheet & Tube Co., Youngstown, O.

PLATE COILS
(A—Ammonia; B—Other refrigerants)

(B) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
(B) Crandal-Stone Div., Brewer-Titchener Corp., 336 Court St., Binghamton, N.Y.
Dean Products, Inc., 1042 Dean St., Brooklyn 16, N.Y. *(p. 154)*
(A,B) Dole Refrigerating Co., 5910 N. Pulaski Rd., Chicago 30, Ill.
(A,B) Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
(B) Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
Stanley Knight Corp., 3430 N. Pulaski Rd., Chicago 41, Ill.
(A,B) Kold-Hold Mfg. Co., 603 E. Hazel St., Lansing 4, Mich.
(A,B) Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. *(p. 209)*
(B) Orley Freezers, Inc., 680 E. Fort St., Detroit 26, Mich.
(A,B) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(B) Standard Refrigeration Co., 232 S. Hoyne Ave., Chicago 20, Ill.
(B) Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.

PLATING (See NAME PLATES)

PLYWOOD

Aetna Plywood & Veneer Co., 1799 Elston Ave., Chicago 22, Ill.
Technical Ply-Woods, 228 N. La Salle St., Chicago 1, Ill.

PORCELAIN, ELECTRICAL

General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Red Spot Elec. Co., Tacoma, Wash.

PORCELAIN ENAMELING (See ENAMELING, PORCELAIN)

PORCELAIN ENAMEL MATERIALS

Chicago Vitreous Enamel Product Co., 1407 S. 55th Court, Cicero 50, Ill.
Ferro Enamel Corp., Harvard & 56th St., Cleveland 5, O.
Ingram Richards Co. of Indiana, Frankfort, Ind.
Pemco Co., 5601 Easter Ave., Batimore 23, Md.

POROUS METAL (See POWDERED METAL PRODUCTS)

POULTRY REFRIGERATORS (See DISPLAY CASES)

POWDERED METAL PRODUCTS

Amplex Div., Chrysler Corp., 6501 Harper Ave., Detroit 31, Mich.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
International Powder Metallurgy Co., 439 W. Main St., Ridgway, Pa.
Keystone Carbon Co., Inc., 1935 State St., St. Marys, Pa.
P. R. Mallory & Co., Inc., 3029 W. Washington St., Indpls., Ind.
Moraine Products Div., Gen'l. Motors Corp., Dayton 1, O.
New Jersey Zinc Co., 160 Front St., N.Y.C. 17

Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.

POWER ELEMENTS

Clifford Mfg. Co., 110 Grove St., Waltham 54, Mass. *(p. 27)*
Fulton Sylphon Co., Div., Robertshaw-Fulton Controls Co., Box 400, Knoxville 4, Tenn.

RESSURE RELIEF DEVICES, REFRIGERANT (See also PRESSURE RELIEF VALVES)

ack, Sivalls & Bryson, Kansas City 3, Mo.
enry Valve Co., Melrose Park, Ill. (*p. 155*)

RESSURE RELIEF VALVES, REFRIGERANT (See also PRESSURE RELIEF DEVICES)

—Ammonia; B—Other refrigerants)

,B) Ashton Valve Co., 161-1st St., Cambridge 42, Mass.
ack, Sivalls & Bryson, Kansas City 3, Mo.
,B) A. W. Cash Co., 540 N. 18th St., Decatur, Ill.
) **Crane Co., 836 Michigan Ave., Chicago 5, Ill.** (*p. 105*)
) **Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill.** (*p. 50*)
rris Engrg. Corp., 400 Commercial Ave., Palisades Park, N.J.
,B) **Frick Co., Waynesboro, Pa.** (*p. 44*)
,B) **Henry Valve Co., Melrose Park, Ill.** (*p. 155*)
,B) **Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill.** (*p. 189*)
) **Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill.** (*p. 110*)
) **Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa.** (*p. 213*)
,B) **King-Zeero Co., 1447 Montrose Ave., Chicago 13, Ill.** (*p. 149*)
) Mueller Brass Co., Port Huron, Mich.
,B) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
,B) Refrigerating Specialities Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
) **Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa.** (*p. 214*)
,B) **Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis.** (*p. 43*)
atts Regulator Co., 10 Embankment St., Lawrence, Mass.
) Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
) Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
,B) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

RESSURE RELIEF VALVES, WATER

shton Valve Co., 161-1st St., Cambridge 42, Mass.
. W. Cash Co., 540 N. 18th St., Decatur, Ill.
limax Engrg. Co., Controls Div., 15 N. Cincinnati, Tulsa, Okla.
onsolidated Brass Co., 139 Summit, Detroit 9, Mich.
rane Co., 836 Michigan Ave., Chicago 5, Ill. (*p. 105*)
lectric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
arris Engrg. Corp., 400 Commercial Ave., Palisades Park, N.J.
lint & Walling Mfg. Co., Inc., 95 Oak St., Kendallville, Ind.
rove Regulator Co., 6529 Hollis St., Oakland, Cal.
. E. Lonergan Co., 2nd & Race Sts., Phila. 6, Pa.
unkenheimer Co., Beekman St. & Waverly Ave., Cin'ti. 14, O.
. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
IcDonnell & Miller, Inc., 1316 Wrigley Bldg., Chicago 11, Ill.
Iinneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. (*p. 70*)
Iueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Iueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
. A. Norgren, 222 Santa Fe Drive, Denver, Col.
aasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
efrigerating Specialities Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
ta-Rite Products, Inc., Delavan, Wis.
I. A. Thrush & Co., 21 E. Riverside Dr., Peru, Ind.
Vatts Regulator Co., 10 Embankment St., Lawrence, Mass.

RESSURESTATS (See CONTROLS)

PRESSURE VESSELS

Alloy Products Corp., 1045 Perkins Ave., Waukesha, Wis.
Richard M. Armstrong Co., Box 188, West Chester, Pa. (*p. 52*)
Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 7
Bethlehem Steel Co., Bethlehem, Pa.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
Black, Sivalls & Bryson, Kansas City 3, Mo.
Bos-Hatten, Inc., 718 E. Elk St., Buffalo, N.Y.
California Steel Products Co., Barrett & "A" Sts., Richmond, Cal.
Colonial Iron Wks. Co., 17643 St. Clair Ave., Cleveland 10, O.
Concrete Forms Corp., 43 Cedar St., N.Y.C. 3
Dersch, Gesswein & Nevert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. (*p. 190*)
John J. Dupps Co., Germantown, O.
Electric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
Fitzsimons Mfg. Co., 3775 E. Outer Dr., Detroit 12, Mich.
Frick Co., Waynesboro, Pa. (*p. 44*)
Fruehauf Trailer Co., 10940 Harper Ave., Detroit 32, Mich. (Transport)
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Gustav Glaser Co., Inc., 2 Wait St., Paterson 4, N.J.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago 1, Ind.
Joseph Kopperman & Sons, 312 New St., Phila. 6, Pa.
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey City 7, N.J.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
McNamara & Co., Inc., 2700 Manokin St., Baltimore 30, Md.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
R. Munroe & Sons Mfg. Corp., 23rd & Smallman Sts., Pittsburgh 22, Pa.
National Tube Co., U. S. Steel Corp. Subsidiary, P.O. Box 266, Pittsburgh, Pa.

(*Continued*)

PRESSURE VESSELS (Continued)

Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55)*
Pressed Steel Tank Co., 1471 S. 66th St., Milwaukee 14, Wis. *(p. 77)*
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Scaife Co., Oakmont, Pa.
A. O. Smith Corp., 3533 N. 27th St., Milwaukee 1, Wis.
Sta-Rite Products, Inc., Delavan, Wis.
H. A. Thrush & Co., 21 E. Riverside Dr., Peru, Ind.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wildman Boiler & Tank Co., 3026 Carroll Ave., Chicago 12, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
Wright-Austin Co., 315 W. Woodbridge St., Detroit 26, Mich.

PRIMERS (See FINISHES)

PRODUCT DEVELOPMENT

U. S. Testing Co., Inc., 1415 Park Ave., Hoboken, N.J. *(p. 156)*

PROGRAM CONTROLLERS (See CONTROLS, PROGRAM; also TIME SWITCHES)

PROOF BOXES, BAKERY

Drying System, Inc., 1810½ Foster Ave., Chicago 40, Ill.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
Fred D. Pfening Co., 1075 W. 5th Ave., Columbus 8, O.
Star Metal Mfg. Co., Inc., Trenton Ave. & Ann St., Phila. 34, Pa.
Union Steel Products Co., 448 Pine St., Albion, Mich. *(p. 182)*

PROPANE

Carbide & Carbon Chemicals Corp., Unit. of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Sun Oil Co., 1608 Walnut St., Phila. 3. Pa.

PROPORTIONING UNITS

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Fischer & Porter Co., Hatboro, Pa.
D. W. Haering & Co., P.O. Box 6037, Dallas, Tex.
Jeffrey Mfg. Co., 887 N. 4th St., Columbus 16, O.

PROPYLENE GLYCOL

Carbide & Carbon Chemicals Corp., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Dow Chemical Co., Midland, Mich.

PSYCHROMETERS

Claude S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
Henry J. Green, 1191 Bedford Ave., Brooklyn 16, N.Y.
E. Vernon Hill, 6826 W. Highland Ave., Chicago 31, Ill
Palmer Thermometers, Inc., 2501 Norwood Ave., Cincinnati 12, O.
Parks-Cramer Co., Box 444, Fitchburg, Mass.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C 12

PULLEYS

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Pulley Co., 4200 Wissahickon Ave., Phila. 29 Pa.
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Charles Bond Co., 617-23 Arch St., Phila., Pa.
Browning Mfg. Co., Inc., Maysville, Ky.
Chicago Die Casting Mfg. Co., 2500 W. Monroe St., Chicago 12, Ill.
Congress Drive Div., Tann Corp., 3750 E. Outer Drive Detroit 34, Mich.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
Dayton Rubber Mfg. Co., 2342 W. Riverview Ave., Dayton 1, O.
R. & J. Dick Co., Inc., 24 Sade St., Passaic, N.J.
Dodge Mfg. Corp., 505 S. Union St., Mishawaka, Ind.
Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
W. A. Jones Foundry & Machine Co., 4401 Roosevelt Rd., Chicago 24, Ill.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Link-Belt Co., 300 Pershing Rd., Chicago 9, Ill.
Maurey Mfg. Corp., 2907 S. Wabash Ave., Chicago 16 Ill.
Menasha Wood Split Pulley Co., 674 Tayco St., Menasha Wis.
Nice Ball Bearing Co., 30th & Hunting Park Ave., Phila. 40, Pa.
Pyott Foundry & Machine Co., 328 N. Sangamon St., Chicago 7, Ill.
Rockwood Mfg. Co., 1801-2001 English Ave., Indpls, Ind.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Chas. A. Schieren Co., 30 Ferry St., N.Y.C. 7
Standard-Keil Hardware Mfg. Co., Inc., 639 B'way. N.Y.C. 12
Swift Mfg. Co., Inc., 1455 E. Nine Mile Rd., Hazel Park. Mich.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*

PULLEYS, ADJUSTABLE

Browning Mfg. Co., Inc., Maysville, Ky.
Chicago Die Casting Mfg. Co., 2500 Monroe St., Chicago 12, Ill.
Congress Drive Div., Tann Corp., 3750 E. Outer Drive, Detroit 34, Mich.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Maurey Mfg. Corp., 2907 S. Wabash Ave., Chicago 16. Ill.
Scientiae Corp., 101 Pine St., Dayton 2, O.
Swift Mfg. Co., Inc., 1455 E. Nine Mile Rd., Hazel Park, Mich.

UMPS, AMMONIA

merican-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
urora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
uffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
old Control, Inc., 111 Broadway, N.Y.C. 6
. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
alter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
astern Industries, Inc., 296 Elm St., New Haven 6, Ct.
airbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
ilter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
oster Pump Wks., Inc., 50 Washington St., Brooklyn 1, N.Y.
oulds Pumps, Inc., Seneca Falls, N.Y.
uild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
awrence Machine & Pump Corp., 371 Market St., Lawrence, Mass.
e Courtenay Co., 5 Maine St., Newark 5, N.J.
harles S. Lewis & Co., 2207 Pine St., St. Louis 3, Mo.
anistee Iron Wks. Co., River St., Manistee, Mich.
eerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave., 26, Los Angeles 31, Cal.
. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
uimby Pump Co., Inc., Div., H. K. Porter Co., 1932 Oliver Bldg., Pittsburgh 22, Pa.
eco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
oots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
eo. D. Roper Corp., 340 Blackhawk Park Ave., Rockford, Ill.
nion Steam Pump Co., Battle Creek, Mich.
iking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
ilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
enry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
orthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
L Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
ork Corp., York, Pa. *(p. 119)*

UMPS, BRINE

merican-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
merican Well Wks., Aurora, Ill.
urora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
uffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
hicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
M. T. Davison Co., 43 Keap St., Brooklyn 11, N.Y.
ean Hill Pump Co., 4000 E. 16th St., Indpls. 7, Ind.
Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Goulds Pumps, Inc., Seneca Falls, N.Y.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., 5327 Jacuzzi Ave., Richmond, Cal.
Lawrence Machine & Pump Corp., 371 Market St., Lawrence, Mass.
Le Courtenay Co., 15 Maine St., Newark 5, N.J.
Charles S. Lewis & Co., 2207 Pine St., St. Louis 3, Mo.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Manistee Iron Wks. Co., River St., Manistee, Mich.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Cal.
Pennsylvania Pump & Compressor Co., Easton, Pa.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Quimby Pump Co., Inc., Div., H. K. Porter Co., 1932 Oliver Bldg., Pittsburgh 22, Pa.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Geo. D. Roper Corp., 340 Blackhawk Park Ave., Rockford, Ill.
Union Steam Pump Co., Battle Creek, Mich.
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Weinman Pump Mfg. Co., 290 Spruce, Columbus 8, O.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.
York Corp., York, Pa. *(p. 119)*

PUMPS, CHEMICAL

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Buffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
Cochrane Corp., 17th St. below Allegheny Ave., Phila. 32, Pa.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Foster Pump Wks., Inc., 50 Washington St., Brooklyn 1, N.Y.
General Ceramics & Steatite Corp., Keasbey, N.J.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
Hills-McCanna Co., 3029 N. Western Ave., Chicago 18, Ill.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Jabsco Pump Co., 2031 N. Lincoln St., Burbank, Cal.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Lawrence Machine & Pump Corp., 371 Market St., Lawrence, Mass.
Le Courtenay Co., 5 Maine St., Newark 5, N.J.
Manistee Iron Wks. Co., River St., Manistee, Mich.
Manzel Inc., 309 Babcock St., Buffalo 10, N.Y.
Nash Engrg. Co., 358 Wilson Rd., S. Norwalk, Ct.
National Lead Co., 111 Broadway, N.Y.C. 6
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave., 26, Los Angeles 31, Cal.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Milton Roy Co., 1401 E. Mermaid Ave., Phila. 18, Pa.
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

PUMPS, COOLANT

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Jabsco Pump Co., 2031 N. Lincoln St., Burbank, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Manistee Iron Wks. Co., River St., Manistee, Mich.
Marlow Pumps, Ridgewood, N.J.
National Lead Co., 111 Broadway, N.Y.C. 6
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Quimby Pump Co., Inc., Div., H. K. Porter Co., 1932 Oliver Bldg., Pittsburgh 22, Pa.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Ruthman Machinery Co., 1810 Reading Rd., Cin'ti., O.
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Whittington Pump & Engrg. Corp., 245 S. Meridian St., Indpls. 4, Ind.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, CORROSION RESISTING

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*

(Continued)

PUMPS, CORROSION RESISTING (Continued)

Buffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
John J. Dupps Co., Germantown, O.
Duriron Co., Inc., Dayton 1, O.
Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Goulds Pumps, Inc., Seneca Falls, N.Y.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
Haveg Corp., Marshallton, Del.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Jabsco Pump Co., 2031 N. Lincoln St., Burbank, Cal.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Johnston Pump Co., 2324 E. 49th St., Los Angeles 11, Cal.
Lawrence Machine & Pump Corp., 371 Market St., Lawrence, Mass.
Le Courtenay Co., 5 Maine St., Newark 5, N.J.
Manistee Iron Wks. Co., River St., Manistee, Mich.
National Carbon Co., Inc., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Peerless Pump Div., Food Machinery & Chemical Corp. 301 West Ave. 26, Los Angeles 31, Cal.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Milton Roy Co., 1401 E. Mermaid Ave., Phila. 18, Pa. (Chemical)
Weinman Pump Mfg. Co., 290 Spruce, Columbus 8, O.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, DEEP WELL

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
American Well Wks., Aurora, Ill.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
A. D. Cook, Inc., Lawrenceburg, Ind.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
Decatur Pump Co., 2750 Nelson Rd., Decatur 70, Ill.
Deming Co., 884 S. Broadway, Salem, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Flint & Walling Mfg. Co., Inc., 95 Oak St., Kendalville, Ind.
Goulds Pumps, Inc., Seneca Falls, N.Y.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Johnston Pump Co., 2324 E. 49th St., Los Angeles 11, Cal.
Layne & Bowler, Inc., P.O. Box 215, Hollywood Sta., Memphis 8, Tenn.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Paul Pumps, Inc., 1700 N. Harrison St., Ft. Wayne 7, Ind.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave., 26, Los Angeles 31, Cal.
A. O. Smith Corp., 3533 N. 27th St., Milwaukee 1, Wis.
Sta-Rite Products, Inc., Delavan, Wis.
Wayne Home Equip. Co., 801 Glasgow Ave., Ft. Wayne 4, Ind.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, FREON & METHYL

Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Buffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Goulds Pumps, Inc., Seneca Falls, N.Y.
Lawrence Machine & Pump Corp., 371 Market St., Lawrence, Mass.
Le Courtenay Co., 5 Maine St., Newark 5, N.J.
Charles S. Lewis & Co., 2207 Pine St., St. Louis 3, Mo.
Typhoon Air Conditioning Co., Inc., Div. of Ice Air Conditioning Co., Inc., 794 Union St., Brooklyn 15, N.Y.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, GEAR

Deming Co., 884 S. Broadway, Salem, O.
Eastern Industries, Inc., 296 Elm St., New Haven, Ct.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicag 5, Ill.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Il
Gray-Mills Corp., 1948 Ridge Ave., Evanston, Ill.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y
Kinney Mfg. Co., 3529 Washington St., Boston 30 Mass. *(p. 16*
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburg 1, Pa.
Geo. D. Roper Corp., 340 Blackhawk Park Ave., Rockford, Ill.
Schutte & Koerting Co., 12th & Thompson Sts., Phila. 2 Pa.
Tuthill Pump Co., 939 E. 95th St., Chicago 19, Ill.
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Watson Flagg Machine Co., 845 E. 25th St., Paterson N.J.
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 11*

PUMPS, HAND

Bello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.
Deming Co., 884 S. Broadway, Salem, O.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Il
Flint & Walling Mfg. Co., Inc., 95 Oak St., Kendallvill Ind.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicag 7, Ill. *(p. 11*
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, I
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Watson-Stillman Co., Roselle, N.J. *(p. 10*
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 11*

PUMPS, HIGH PRESSURE

Aldrich Pump Co., Allentown, Pa.
American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 15*
Cooper-Bessemer Corp., Mt. Vernon, O.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
DeLaval Steam Turbine Co., 853 Nottingham Wa Trenton 2, N.J.
John J. Dupps Co., Germantown, O.
Eastern Industries, Inc., 296 Elm St., New Haven, Ct.
Economy Pumps, Inc., Hamilton, O.
Eisler Engrg. Co., Inc., 740 S. 13th St., Newark 3, N.J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicag 5, Ill.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Lo Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Johnston Pump Co., 2324 E. 49th St., Los Angeles 11, Ca
Le Courtenay Co. 5 Maine St., Newark 5, N.J.
Leiland Bros., Inc., 100 Christie St., Newark 5, N.J.
Manistee Iron Wks. Co., River Rd., Manistee, Mich.
Nathan Mfg. Co., 416 E. 106th St., N Y.C. 29
Geo. D. Roper Corp., 340 Blackhawk Park Ave., Rock ford, Ill.
Sta-Rite Products, Inc., Delavan, Wis.
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 116*
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Il

PUMPS, JET

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E. Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159*
Cold Control, Inc., 111 Broadway, N.Y.C. 6
Flint & Walling Mfg. Co., Inc., 95 Oak St., Kendallville Ind.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia
Paul Pumps, Inc., 1700 N. Harrison St., Ft. Wayne 7, Ind
Peerless Pump Div., Food Machinery & Chemical Corp. 301 West Ave., 26, Los Angeles 31. Cal.
Sta-Rite Products, Inc., Delavan, Wis.
Tranter Mfg. Co., 105 Water St., Pittsburgh 22, Pa.
Wayne Home Equip. Co., 801 Glasgow Ave., Ft. Wayn 4, Ind.
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 11*

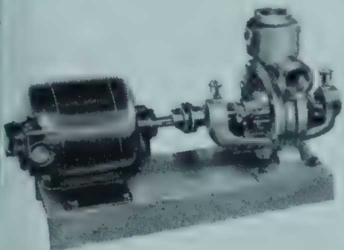
AURORA PUMP COMPANY

401 Loucks Street, Aurora (Chicago Suburb) Illinois

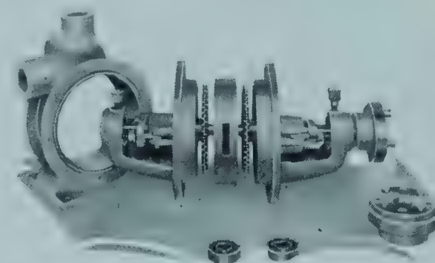
Manufacturers of

Turbine-Type, Vertical and Horizontal Centrifugal and Special Design Pumps

Distributors in Principal Cities

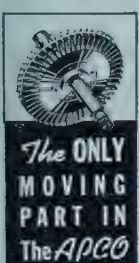

Apco Single Stage Turbine-Type Pumps.

A COMPLETE STOCK MAINTAINED for IMMEDIATE SHIPMENT


Disassembled View Two Stage Apco Turbine-Type Pumps for high pressure duty.

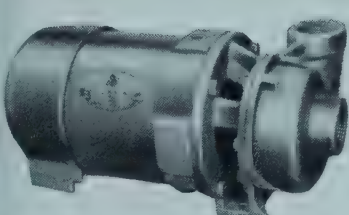
CAPACITIES UP TO 150 G.P.M.—HEADS TO 600 FT.

APCO PUMPS are IDEALLY SUITED to MANY REFRIGERATION DUTIES



FEATURES—APCO pumps are distinguished for their ability to deliver small capacities against high heads; their ability to deliver with but slight change in capacity or efficiency against drastic head variations. They possess these advanced features—SIMPLE—WEAR-FREE—COMPACT · HIGH EFFICIENCY · WILL NOT VAPOR BIND · PERFECT HYDRAULIC BALANCE · ACCESSIBILITY · HIGH SUCTION LIFT (28 ft. at sea level) · QUIET OPERATION · HIGH PRESSURE PER STAGE · DOUBLE SUCTION DESIGN · PRECISION SHAFTS · BALL BEARINGS (Support on both sides of impeller) · RIGHT OR LEFT HAND OPERATION (Changeable in Field without special parts) · REPLACEABLE COVER PLATES · AVAILABLE IN VARIOUS CORROSION RESISTANT ALLOYS.

LOW HEAD · SMALL CAPACITY—SIDE SUCTION PUMPS · MEDIUM HEAD

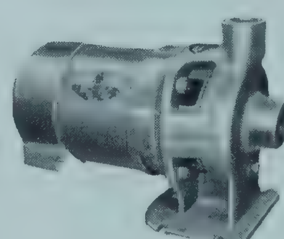

TYPE—SAC—Close Coupled
Caps. 5 to 85 G.P.M.
Heads to 45 Ft.
Sizes Available ¾", 1¼", 2"

APPLICATIONS

These pumps are ideally suited for use as integral part of Equipment Manufacturer's product, such as, air conditioning units, cooling towers, evaporator coolers, milk coolers, hot water circulators etc.; also for general service.

CONSTRUCTION SPECIFICATIONS

Made in bronze fitted, all iron or all bronze construction


TYPE—JMC—Close Coupled
Caps. 5 to 110 G.P.M.
Heads to 100 Ft.
Sizes Available 1", 1¼", 1½", 2"

CASINGS vertically split—End suction design—Made of high grade material as specified. Casing wearing ring standard construction on Type JMC.

MECHANICAL SEAL is standard equipment on all sizes and is located in packing cover—easily replaceable.

IMPELLER is balanced of enclosed type and made of high grade bronze material.

SHAFTS—Stainless Steel on Types JMC, SAC and JA. Can be furnished on Type SA at additional cost.

MOTOR built to NEMA specifications and equipped with STAINLESS STEEL shaft.

BALL BEARINGS—Permanently sealed against dust and moisture—No lubrication required.

AURORA CENTRIFUGAL PUMPS

—are available in a complete range of types and sizes to meet the manifold requirements of industry. These products of exclusive pump manufacturers are of outstanding quality in design, material and workmanship. Aurora Centrifugal Pumps are distinguished for their streamline designed impellers and waterways to insure maximum flow with least resistance and an avoidance of the turbulance which commonly causes cavitation and consequent corrosion.

WRITE TODAY for CONDENSED CATALOG "R"

PUMPS, MIDGET

Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct
Economy Pumps, Inc., Hamilton, O.
Eimer & Amend, 633 Greenwich St., N.Y.C. 14

PUMPS, OIL

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p.96)*
Bowser, Inc., 1302 E. Creighton Ave., Ft. Wayne 2, Ind.
Buffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Foster Pump Wks., Inc., 50 Washington St., Brooklyn 1, N.Y.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Kinney Mfg. Co., 3529 Washington St., Boston 30, Mass. *(p. 163)*
Le Courtenay Co., 5 Maine St., Newark 5, N.J.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Nathan Mfg. Co., 416 E. 106th St., N.Y.C. 29
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Cal.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Racine Tool & Machine Co., 1000 Carlisle Ave., Racine, Wis.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Geo. D. Roper Corp., 340 Blackhawk Park Ave., Rockford, Ill.
Union Steam Pump Co., Battle Creek, Mich.
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, POSITIVE PRESSURE

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E. Battle Creek, Mich.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
Leiman Bros., Inc., 100 Christie St., Newark 5, N.J.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave. 26, Los Angeles 31, Cal.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Milton Roy Co., 1401 E. Mermaid Ave., Phila. 18, Pa. (Chemical)
Sta-Rite Products, Inc., Delavan, Wis.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, SHALLOW WELL

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Decatur Pump Co., 2750 Nelson Park Rd., Decatur 70, Ill.
Deming Co., 884 S. Broadway, Salem, O.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Flint & Walling Mfg. Co., Inc., 95 Oak St., Kendallville, Ind.
Jabsco Pump Co., 2031 N. Lincoln St., Burbank, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Johnston Pump Co., 2324 E. 49th St., Los Angeles 11, Cal.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Marlow Pumps, Ridgewood, N.J.
Paul Pumps, Inc., 1700 N. Harrison St., Ft. Wayne 7, Ind.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave., 26, Los Angeles 31, Cal.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
Sta-Rite Products, Inc., Delavan, Wis.
Wayne Home Equip. Co., 801 Glasgow Ave., Ft. Wayne 7, Ind.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, SPECIAL

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Johnston Pump Co., 2324 E. 49th St., Los Angeles 11, Cal.
Lawrence Machine & Pump Corp., 371 Market St., Lawrence, Mass.
Le Courtenay Co., 5 Maine St., Newark 5, N.J.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
Milton Roy Co., 1401 E. Mermaid Ave., Phila. 18, Pa. (Chemical)
Sta-Rite Products, Inc., Delavan, Wis.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

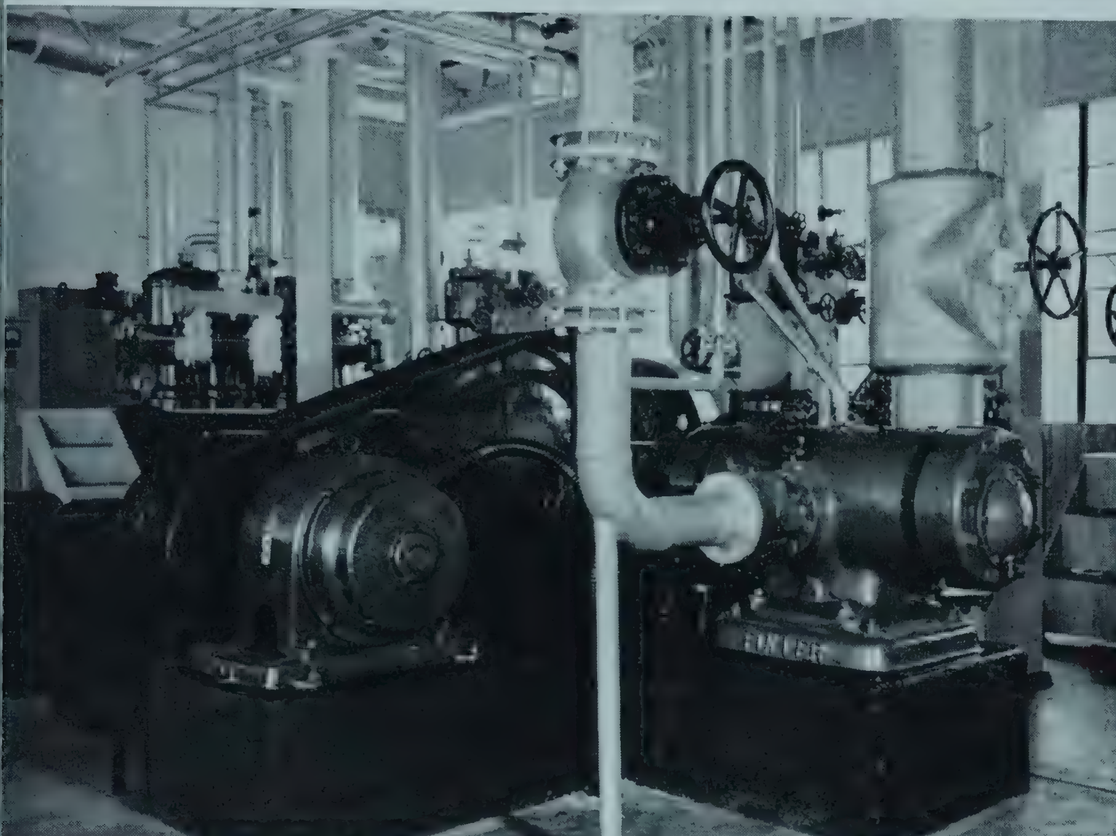
PUMPS, SUBMERSIBLE

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Economy Pumps, Inc., Hamilton, O.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Lawrence Machine & Pump Corp., 371 Market St., Lawrence. Mass.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
Sta-Rite Products, Inc., Delavan, Wis.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, SUMP

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Buffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
Columbus Steam Pump Wks. Co., 724 W. Gay St., Columbus 8, O.
A. D. Cook, Inc., Lawrenceburg, Ind.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
Eastern Industries, Inc., 296 Elm St., New Haven, Ct.
Economy Fauncet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Flint & Walling Mfg. Co., Inc., 95 Oak St., Kendallville, Ind.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Jabsco Pump Co., 2031 N. Lincoln St., Burbank, Cal.
Byron Jackson Co., P.O. Box 2017 Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Johnston Pump Co., 2324 E. 49th St., Los Angeles 11, Cal.
Lawrence Machine & Pump Corp., 271 Market St., Lawrence, Mass.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.

(Continued)



FULLER
ROTARY COMPRESSORS

- COMPACT
- EFFICIENT
- ECONOMICAL

Fuller Rotary Compressors are ideal as "low-pressure boosters" for the refrigeration and frozen foods industries—by reason of their smooth operation and space saving features, as compared with other types of machines of like capacity. Blades automatically compensate for wear, thus capacity is maintained for the life of the machine. Fullers are available for capacities, on air, to 3300 c.f.m. For vacuums to 29.90-inch (referred to 30-inch barometer).

The Fuller Rotary Compressor illustrated above was installed in a plant in California, and after a year of continuous operation, the plant manager advised that no repairs or service was necessary. He further states that, "For the time our Fuller has been in operation it has been entirely satisfactory. The simplicity of this machine makes it very economical to operate."

Fuller Rotaries have been in operation for over twenty years in many industrial plants in this and other countries. For more information write for Bulletin C-5.

fuller

FULLER COMPANY, Box 420, Catasauqua, Pa.
120 So. LaSalle St., Chicago 3
420 Chancery Bldg., San Francisco 4

C-206

PUMPS, SUMP (Continued)

Marlow Pumps, Ridgewood, N.J.
Paul Pumps, Inc., 1700 N. Harrison St., Ft. Wayne 7, Ind.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave., 26, Los Angeles 31, Cal.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Standard Elec. Mfg. Co., W. Berlin, N.J.
Sta-Rite Products, Inc., Delavan, Wis.
Swaby Mfg. Co., 3818 W. Armitage Ave., Chicago 47, Ill.
Wayne Home Equip. Co., 801 Glasgow Ave., Ft. Wayne 4, Ind.
Weinman Pump Mfg. Co., 290 Spruce, Columbus 8, O.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 12, Ill.

PUMPS, VACUUM

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Barrett, Haentjens & Co., Hazleton, Pa.
Beach-Russ Co., 50 Church St., N.Y.C. 7 *(p. 162)*
Bury Compressor Co., 1712 Cascade St., Erie, Pa.
Central Scientific Co., 1700 Irving Park Blvd., Chicago, Ill.
Cochrane Corp., 17th St. below Allegheny Ave., Phila. 32, Pa.
Columbus Steam Pump Wks. Co., 724 W. Gay St., Columbus 8, O.
Croll-Reynolds Engrg. Corp., Inc., 17 John St., N.Y.C.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
Distillation Products, Inc., 755 Ridge Rd., W., Rochester 13, N.Y.
C. A. Dunham Co., 400 W. Madison St., Chicago 6, Ill.
John J. Dupps Co., Germantown, O.
Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Eisler Engrg. Co., Inc., 7430 S. 13th St., Newark 3, N.J.
Foster Pump Wks., Inc., 50 Washington St., Brooklyn 11, N.Y.
Fuller Co., Box 42, Catasauqua, Pa. *(p. 161)*
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Jabsco Pump Co., 2031 N. Lincoln St., Burbank, Cal.
Kinney Mfg. Co., 3529 Washington St., Boston 30, Mass. *(p. 163)*
Leiman Bros., 100 Christie St., Newark 5, N.J.
Lummus Co., 420 Lexington Ave., N.Y.C.
Nash Engrg. Co., 358 Wilson Rd., S. Norwalk, Ct.
Pennsylvania Pump & Compressor Co., Easton, Pa.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Ross Heater & Mfg. Co., Div. of American Radiator & Standard Sanitary Corp., Buffalo 13, N.Y.
F. J. Stokes Machine Co., Tabor Rd., Phila. 20, Pa.
Union Steam Pump Co., Battle Creek, Mich.
Whittington Pump & Engrg. Corp., 245 S. Meridian St., Indpls. 4, Ind.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

PUMPS, VANE

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
American Well Wks., Aurora, Ill.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Brown & Sharpe Mfg. Co., 235 Promenade St., Providence 1, R.I.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Foster Pumps., Inc., 50 Washington St., Brooklyn 1, N.Y.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Peerless Pump Div., Food Machinery & Chemical Corp., 301 West Ave., 26, Los Angeles 31, Cal.
Trimount Rotary Power Co., 189 Cedar St., Bedham, Mass.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

Kinney Manufacturing Company

Boston 30, Massachusetts

NEW YORK 7 **30 Church St.**	**CLEVELAND 15** **2036 E. 22nd St.**	**CHICAGO 5** **59 E. Van Buren St.**
PHILADELPHIA 2 **16 Commercial Trust Bldg.**	**LOS ANGELES 43** **3942 West Slauson Ave.**	**SAN FRANCISCO 7** **774 Folsom St.**

KINNEY HIGH VACUUM PUMPS

Mechanical, Oil Sealed

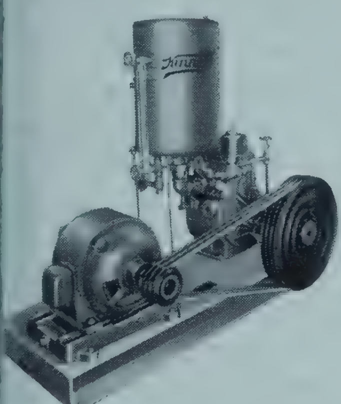
Kinney Dry Vacuum Pumps are standard equipment in the plants of the principal ıanufacturers of household refrigerators and quick freeze units for drying coils, ompressor units and drying oil. They are also standard equipment in the plants roducing temperature control units. Good mechanical performance coupled with igh volumetric efficiency at the high vacuums needed to insure moisture-free and ir-free units make Kinney Vacuum Pumps a necessity for such work. The same igh performance is desirable for repair shops.

Kinney Vacuum Tight Valves insure tight systems.

We recommend Kinney heated separator tanks when excessive moisture is present n the system to be exhausted.

SINGLE STAGE VACUUM PUMPS

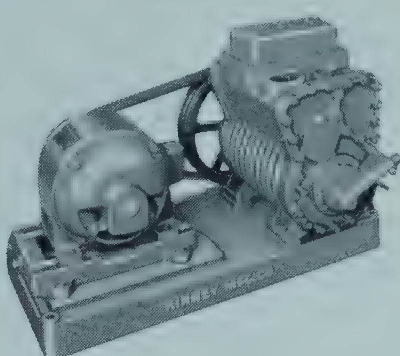
Models VSD and DVD



Eight pump sizes are available (13, 27, 46, 110, 217, 311, 486 and 702 cu. ft. per min.) with motors from ½ to 40 h.p. The three smallest sizes are furnished water cooled or air cooled; all larger sizes are furnished water cooled. Single Stage Pumps on a blank test will produce absolute pressure readings of 10 microns (.01 mm Hg.) or better.

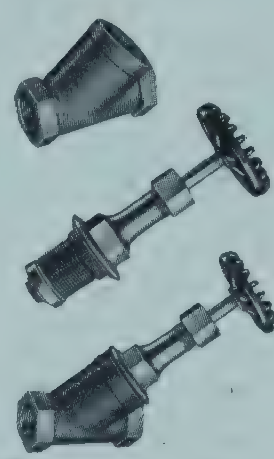
COMPOUND VACUUM PUMP

Model CVD



Two pump sizes are available (15 and 46 cu. ft. per min.) with 1 and 3 h.p. motors. The working mechanism is similar to the Single Stage but the two cylinders are connected in series. The Compound Pump has an air cooled casing of unique design and special provision for oil sealing and lubricating the high vacuum working parts. Low absolute pressures to 0.5 micron (.0005 mm Hg.) are regularly maintained.

VACUUM TIGHT VALVES



Kinney Vacuum Tight Valves greatly facilitate testing installations. They are constructed with a specially designed metal bellows, eliminating the usual stuffing box. Leakage has been reduced to .000,000,007 cu. ft. per second. Available in sizes 1″, 1½″, 2″ and 3″.

Ask for Kinney Vacuum Pump Bulletin V45.

PUMPS, WATER

American-Marsh Pumps, Inc., 1948 Capitol Ave., N.E., Battle Creek, Mich.
Aurora Pump Co., 178 Loucks St., Aurora, Ill. *(p. 159)*
Thomas Beckett & Co., Inc., P.O. Box 7354, Dallas 2, Tex.
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Ill.
Buffalo Pumps, Inc., 465 Broadway, Buffalo 4, N.Y.
Chicago Pump Co., 2300 Wolfram St., Chicago 18, Ill.
M. T. Davidson Co., 43 Keap St., Brooklyn 11, N.Y.
Decatur Pump Co., 2750 Nelson Park Rd., Decatur 70, Ill.
Walter H. Eagan Co., Inc., 2336 Fairmount Ave., Phila. 30, Pa.
Eastern Engrg., 45 Fox St., New Haven, Ct.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Economy Faucet Co., 12 New York Ave., Newark, N.J.
Economy Pumps, Inc., Hamilton, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Flint & Walling Mfg. Co., Inc., 95 Oak St., Kendallville, Ind.
Foster Wheeler Corp., 165 Broadway, N.Y.C.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Jabsco Pump Co., 2031 N. Lincoln St., Burbank, Cal.
Byron Jackson Co., P.O. Box 2017, Terminal Annex, Los Angeles 54, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Johnston Pump Co., 2324 E. 49th St., Los Angeles 11, Cal.
Lawrence Machine & Pump Corp., 371 Market St., Lawrence, Mass.
Layne & Bowler, Inc., P.O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Le Courtenay Co., 5 Maine St., Newark 5, N.J.
Charles S. Lewis & Co., 2207 Pine St., St. Louis 3, Mo.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Manistee Iron Wks. Co., River Rd., Manistee, Mich.
Marlow Pumps, Ridgewood, N.J.
National Engrg. & Mfg. Co., 519 Wyandotte, Kansas Cit 6, Mo. (Evaporator Cooler Pumps)
Paul Pumps, Inc., 1700 N. Harrison St., Ft. Wayne 7, Ind
Peerless Pump Div., Food Machinery & Chemical Corp 301 West Ave., 26, Los Angeles 31, Cal.
Pennsylvania Pump & Compressor Co., Easton, Pa.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburg 1, Pa.
Quimby Pump Co., Inc., Div., H. K. Porter Co., 1932 Ol ver Bldg., Pittsburgh 22, Pa.
Standard Elec. Mfg. Co., W. Berlin, N.J.
Sta-Rite Products, Inc., Delavan, Wis.
Union Steam Pump Co., Battle Creek, Mich.
Utility Appliance Corp., 4851 S. Alameda St., Los Angele 11, Cal.
Viking Pump Co., 4th & Squire Sts., Cedar Falls, Ia.
Wayne Home Equip. Co., 801 Glasgow Ave., Ft. Wayn 4, Ind.
Weinman Pump Mfg. Co., 290 Spruce, Columbus 8, O.
Worthington Pump & Machinery Corp., Harriso N.J. *(p. 11*
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Il

PURGERS, REFRIGERANT

Armstrong Machine Wks., 831 Maple St., Thre Rivers, Mich. *(p. 16*
Baker Refrigeration Corp., S. Windham, Me. *(p. 4*
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Guild & Garrison, Inc., 43 Keap St., Brooklyn 11, N.Y
Mueller Brass Co., Port Huron, Mich.
Reco Products Div., Refrigeration Engrg., Corp., 202 Naudain St., Phila. 46, Pa.
Rex Engrg. & Sales Co., Box 4151, Oklahoma City, Okl
Worthington Pump & Machinery Corp., Harriso N.J. *(p. 11*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 11*

URIFIERS, WATER (See WATER TREATING)

UICK FREEZE CABINETS (See FARM & HOME FREEZERS)

UICK FREEZERS (See FREEZERS)

ACK, GEAR & PINION

everage Engrg. & Equip. Co., 13301 Lakewood Hts. Blvd., Cleveland 7, O.
ink-Belt Co., 300 Pershing Rd., Chicago 9, Ill.
tandard Steel Specialty Co., Beaver Falls, Pa.

ACKS, WIRE (See WIRE FORMING)

ADIATION, ULTRA-VIOLET (See LAMPS, BACTERICIDAL)

AILROAD REFRIGERATION SYSTEMS

old Control, Inc., 111 Broadway, N.Y.C. 6
rigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
ay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
orth American Distributing Corp., 415 Lexington Ave., N.Y.C. 17 *(p. 166)*
ropane Development Corp., 41 Murray St., N.Y.C. 7

REACH-IN REFRIGERATORS (See REFRIGERATORS, REACH-IN)

RECEIVERS

Acklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*
Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
Baker Refrigeration Co., S. Windham, Me. *(p. 48)*
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Ill,
Bossert Co., P.O. Drawer 358, Utica 1, N.Y.
Cold Control, Inc., 111 Broadway, N.Y.C. 6
Davis Engrg. Corp., 1064 E. Grand St., Elizabeth 4, N.J.
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32) N.Y. *(p. 56)*
Fitzsimons Mfg. Co., 3775 E. Outer Dr., Detroit 12, Mich.
Frick Co., Waynesboro, Pa. *(p. 44)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Houdaille-Hershey Corp., 1900 Foss Park Ave., N. Chicago, Ill. *(p. 165)*
Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
Joy Mfg. Co., Oliver Bldg., Pittsburgh 22, Pa.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55)*
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Reynolds Mfg. Co., Inc., Springfield, Mo.
Richmond Engrg. Co., Inc., 7th & Hospital Sts., Richmond 19, Va.
Roessing Mfg. Co., Sharpsburg Sta., Pittsburgh, Pa.
Scaife Co., Oakmont, Pa.
Standard Heater & Oil Equip. Co., 245 Cornelison Ave., Jersey City 2, N.J.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

RECEPTACLES, ELECTRICAL

General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hart Mfg. Co., 110 Bartholomew Ave., Hartford 1, Ct.

Pent Elec. Co., Inc., 634 Michigan Trust Bldg., Grand Rapids 2, Mich.
Pyle Nat'l. Co., 1371 W. 37th St., Chicago 9. Ill.

RECIRCULATING INJECTORS (See INJECTORS)

RECORDERS, HUMIDITY

Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh 8, Pa.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Ess Instrument Co., 965 Washington Ave., Bergenfield, N.J.
Friez Instrument Div., Bendix Aviation Corp., Taylor Ave. at Loch Raven Blvd., Towson, Baltimore 4, Md.
Leeds & Northrup Co., 4970 Stenton Ave., Phila. 44, Pa.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti. 12, O.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12

RECORDERS, PRESSURE

Ashcroft Gauge Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Ashton Valve Co., 161-1st St., Cambridge 42, Mass. *(p. 168)*
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Distillation Products, Inc., 755 Ridge Rd., W. Rochester 13, N.Y.
Esterline-Angus Co., Inc., P.O. Box 596, Indpls. 6, Ind.
Hays Corp., Michigan City, Ind.
Manning, Maxwell & Moore, Inc., Stratford, Ct.
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti. 12, O.
F. J. Stokes Machine Co., Tabor Rd., Phila. 20, Pa.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12

RECORDERS, TEMPERATURE (See THERMOMETERS, RECORDING)

RECTIFIERS

Louis Allis Co., 427 E. Stewart St., Milwaukee 7, Wis.
Fansteel Metallurgical Corp., N. Chicago, Ill.
Federal Telephone & Radio Corp., 900 Passaic Ave., E. Newark, N.J.

(Continued)

RECTIFIERS (Continued)

General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

REDUCERS, SPEED (See SPEED CHANGERS)

REFRIGERANTS (See also particular refrigerant)

Ansul Chemical Co., Marinette, Wis. *(p. 167)*
Henry Bower Chemical Mfg. Co., Gray's Ferry Rd. & 29th St., Phila. 46, Pa.
Carbide & Carbon Chemicals Corp., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Electrochemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Eston Chemicals, Inc., 3100 E. 26th St., Los Angeles 23, Cal.
Kinetic Chemicals, Inc., 10th & Market Sts., Wilmington, Del. *(p. 113)*
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
Virginia Smelting Co., W. Norfolk, Va. *(p. 168)*

REFRIGERATION SYSTEMS, PORTABLE

North American Distributing Corp., 415 Lexington Ave., N.Y.C. 17 *(p. 166)*

REFRIGERATORS (See particular type; also DISPLAY CASES; also WALK-IN COOLERS, etc.)

REFRIGERATORS, BIOLOGICAL

Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Bowser, Inc., Terryville, Ct.
Eimer & Amend, 633 Greenwich St., N.Y.C. 14
Foster Refrigerator Corp., Mill & N. 2nd St., Hudson, N.Y.
Gennett & Sons, Inc., 1 Main St., Richmond, Ind.
Hugo Mfg. Co., 49 Ave. W. & Superior St., Duluth 10, Minn.
Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
McCall Refrigerator Corp., Hudson, N.Y.
John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.

REFRIGERATORS, FLORISTS
(A—Self-contained; B—With coils but without condensing unit; C—No coils or condensing unit)

Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
(A) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
(B) Cruse Refrigerator Co., Inc., 504 W. Main St., Louisville 2, Ky.
(A,B,C) Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, Pa.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(A,B) Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
(A,B) Fleetwood-Airflow, Inc., 421 N. Penna Ave., Wilkes-Barre, Pa.
(A,B,C) Fogel Refrigerator Co., 5400 Eadom St., Phila 37, Pa.
(A,B) Ed Friedrich, Inc., 1117 E. Commerce St., San Antonio 6, Tex.
(A,B,C) Gem Refrigerator Co., 2539 Germantown Ave., Phila. 33, Pa.
(B) John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
(A,B,C) Herrick Refrigerator Co., 1019 Commercial St., Waterloo, Ia. *(p. 170)*
(B) C. V. Hill & Co., Inc., 360 Pennington Ave., Trenton 1, N.J.
(B) Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
(A,B,C) Jordon Refrigerator Co., 235 N. Broad St., Phila 7, Pa.
(A,B,C) Jack Langston Co., 3700 Elm St., Dallas 1, Tex.
(A,B,C) Lingle Refrigerator Co., Inc., 1116 E. 15th St., Kansas City 6, Mo.
McCall Refrigerator Corp., Hudson, N.Y.
(B) McCray Refrigerator Co., Kendallville, Ind.
(A,B) Masterfreeze Corp., Sister Bay, Wis.
(A,B,C) Minneapolis Show Case & Fixture Co., 1009 Washington Ave., S., Minneapolis, Minn.
(B) Morton Show Cases, Inc., Washington Courthouse, O.
(A,B,C) John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
(A,B,C) National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
(A,B,C) Nolin Mfg. Co., Inc., 1100 Madison Ave., Montgomery 2, Ala.
(A) Perfecold, Inc., 1940 S. Main St., Los Angeles 7, Cal.
(A,B) Puffer-Hubbard Mfg. Co., Grand Haven, Mich.
(A,B) C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
(B) Schwenger-Klein, Inc., 720 Bolivar Rd., Cleveland, O.
(A,B) Seeger Refrigerator Co., 850 Arcade St., St. Paul 6, Minn.
(B) Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
(A,B) Simplex Mfg. Co., 1135-3rd St., Oakland 20, Cal.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
Tyler Fixture Corp., 1401 Lake St., Niles, Mich. *(p. 80)*
Tyson Metal Products, 615 Hamilton Ave., Pittsburgh 8, Pa.
Viking Refrigerators, Inc., 7500 Wilson Ave., Kansas City 3, Mo.
(A,B,C) Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.
(B) Warren Co., Inc., P.O. Box 1436, Atlanta 1, Ga.
(A,B,C) Weber Showcase & Fixture Co., Inc., P.O. Box 2018, Los Angeles 54, Cal.

REFRIGERATORS, FOOD SERVICE (See REFRIGERATORS, REACH-IN)

Virginia Smelting Co.

West Norfolk, Virginia

or F. A. Eustis, 131 State Street, Boston 4, Massachusetts—76 Beaver Street, New York 5, New York

Factory stocks: West Norfolk, Virginia; Jersey City, New Jersey; Boston, Massachusetts and other principal cities.

VIRGINIA

Refrigerants

"Virginia" Refrigerants are produced under the direction of skilled technicians who recognize the importance of high purity standards for refrigeration use.

"EXTRA DRY ESOTOO" ("Virginia" Sulfur Dioxide, SO_2)

A water-white, oil-free product guaranteed to contain less than 50 P.P.M. moisture. Shipped in cylinders containing 10, 35 and 150 lbs. net weight; drums containing 1965 lbs. net C.L. or L.C.L.

"V-METH-L" ("Virginia" Methyl Chloride, CH_3Cl)

Low moisture and low acidity specifications, freedom from dirt and oil characterize this product—an ideal refrigerant for commercial applications.

Shipped in cylinders containing 18, 24, 65, 100, 145, and 300 lbs. net weight and in drums containing 1,340 lbs. net, C.L. or L.C.L.

METHYLENE CHLORIDE (CH_2Cl_2)

Highly refined to conform to strictest refrigeration purity standards—for household refrigerators and centrifugal air conditioning compressors. Shipped in steel drums containing 550 lbs. net weight.

Write for free Booklet #36 "Tabulated Properties of Various Refrigerants"

• AVAILABILITY •

Prompt shipment from "Virginia" manufacturing plant; from emergency stocks located in key distribution centers and from refrigeration supply jobbers in all principal cities from coast to coast.

DISTRIBUTORS FOR KINETICS' "FREON-12," "FREON-22," "FREON-11," "FREON-21," "FREON-113," AND "FREON-114"

REFRIGERATORS, HOUSEHOLD, ELECTRIC

Acme-Nat'l. Refrigeration Co., Inc., 634 Dean St., Brooklyn 17, N.Y.
Admiral Corp., 3800 Cortland St., Chicago 47, Ill.
Coolerator Co., 50 Ave. W. and Wadena St., Duluth 1, Minn.
Copeland Refrigeration Corp., Sidney, O. *(p. 63)*
Crosley Div., Avco Corp., Cin'ti. 25, O.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Franklin Transformer Mfg. Co., Inc., 65-22nd, N.E., Minneapolis 18, Minn.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., 1285 Boston Ave., Bridgeport 2, Ct.
Gibson Refrigerator Co., 515 W. Williams St., Greenville, Mich.
Hotpoint, Inc., 5600 W. Taylor St., Chicago 44, Ill.
International Harvester Co., 180 N. Michigan Ave., Chicago 1, Ill.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit 5, Mich. *(p. 59)*
Leonard Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit 32, Mich.
Marvel Industries, Inc., 14600 E. Seven Mile Rd., Detroit 5, Mich.
National Cooperatives, Inc., 343 S. Dearborn St., Chicago 4, Ill.
Norge Div., Borg-Warner Corp., 670 E. Woodbridge St., Detroit 26, Mich.
Orley Freezers, Inc., 680 E. Fort St., Detroit 26, Mich.
Philco Corp., Tioga & C Sts., Phila. 34, Pa.
Ranney Refrigerator Co., Greenville, Mich. *(p. 169)*
Sanitary Refrigerator Co., Fond du Lac, Wis.
Universal Refrigeration Co., 5601 W. Century Blvd., Inglewood, Cal.
Westinghouse Elec. Corp., Mansfield, O.

REFRIGERATORS, HOUSEHOLD, GAS

Clayton & Lambert, 1701 Dixie Highwy., Louisville, Ky.
Servel, Inc., Evansville 20, Ind.

REFRIGERATORS, HOUSEHOLD, ICE

American Commercial Equip. Co., 4150 Holly Knoll, Los Angeles 27, Cal.
Coolerator Co., 50 Ave. W. and Wadena St., Duluth 1, Minn.
Ice Cooling Appliance Corp., Morrison, Ill.
Modern Refrigerator Wks., 823 Milford St., Glendale 3, Cal.
Sanitary Refrigerator Co., Fond du Lac, Wis.

REFRIGERATORS, HOUSEHOLD, PRIVATE LABEL

Artkraft Mfg. Co., E. Kibbey St., Lima, O.
Franklin Transformer Mfg. Co., Inc., 65-22nd., N. E., Minneapolis 18, Minn.
Crosley Div., Avco Corp., Cin'ti. 25, O.
Ranney Refrigerator Co., Greenville, Mich. *(p. 169)*

REFRIGERATORS, LOW TEMPERATURE FOR LABORATORY & INDUSTRIAL USE

Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Bowser, Inc., Terryville, Ct.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Chapman & Wood Refrigeration, 4825 Southwest Pomona, Portland 19, Ore.
Eimer & Amend, 633 Greenwich St., N.Y.C. 14
Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
Foster Refrigerator Corp., Mill & N. 2nd St., Hudson, N.Y.
Frick Co., Waynesboro, Pa. *(p. 44)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Herrick Refrigerator Co., 1019 Commercial St., Waterloo, Ia. *(p. 170)*
Hussman Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
Lingle Refrigerator Co., Inc., 1116 E. 15th St., Kansas City 6, Mo.
McCray Refrigerator Co., Kendallville, Ind.
John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
J. P. Pfeiffer & Son, Inc., 200 N. Paca St., Baltimore 1, Md.
Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
Emil Steinhorst & Sons, Inc., 612 South St., Utica 3, N.Y.
Victor Products Corp., 901 Pope Ave., Hagerstown, Md.
York Corp., York, Pa. *(p. 119)*

REFRIGERATORS, MORTUARY

Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.
John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
Herrick Refrigerator Co., 1019 Commercial St., Waterloo, Ia. *(p. 170)*
Lingle Refrigerator Co., Inc., 1116 E. 15th St., Kansas City 6, Mo.
J. P. Pfeiffer & Son, Inc., 200 N. Paca St., Baltimore 1, Md.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.

REFRIGERATORS, REACH-IN

(A—Self-contained; B—With coils but without condensing unit; C—No coils or condensing unit; D—Ice refrigerated)

(A) Airtemp Div., Chrysler Corp., 1119 Leo St., Dayton 1, O.
(C) **Annapolis Yacht Yard, Box 791, Annapolis, Md.** *(p. 216)*
Bally Case & Cooler Co., Bally, Pa.
(A,B) **Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y.** *(p. 45)*
Chapman & Wood Refrigeration, 4525 Southwest Pomona, Portland 19, Ore.
(A,B,D) Cruse Refrigerator Co., Inc., 504 W. Main St., Louisville 2, Ky.
Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, Pa.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(A,B) Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.

(Continued)

REFRIGERATORS, REACH-IN (Continued)

(A,B,C,D) Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.
(A,B) Foster Refrigerator Corp., Mill & N. 2nd St., Hudson, N.Y.
(A,B,D) Ed Friedrich, Inc., 1117 E. Commerce St., San Antonio 6, Tex.
(A) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(A,B,C,D) Gem Refrigerator Co., 2539 Germantown Ave. Phila. 33, Pa.
(A) General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
(B) John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
(A,B,C,D) Herrick Refrigerator Co., 1019 Commercial St., Waterloo, Ia. *(p. 170)*
(A,B) C. V. Hill & Col, Inc.,360 Pennington Ave., Trenton 1, N.J.
(A) Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
(A,B,C,D) Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
(A,B,C) La Crosse Cooler Co., 2809 Losey Blvd., S., La Crosse, Wis.
(A,B,C) Lingle Refrigerator Co., Inc., 1116 E. 15th St. Kansas City 6, Mo.
(A,B,C) Jack Langston Co., 3700 Elm St., Dallas 1, Tex.
McCall Refrigerator Corp., Hudson, N.Y.
(A,B) McCray Refrigerator Co., Kendallville, Ind.
(A,B) Masterfreeze Corp., Sister Bay, Wis.
Matthews Refrigerator & Door Co., 5103 S.E. Powell Blvd., Portland 6, Ore.
(A,B,C) Minneapolis Show Case & Fixture Co., 1009 Washington Ave., S., Minneapolis, Minn.
(B) Morton Show Cases, Inc., Washington Courthouse, O.
(A,B,C) John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
(A,B) Nanticoke Refrigerator Manufacturers, Corner Hill & Slope Sts., Nanticoke, Pa.
(A,B,C,D) National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
(A,B,C) Nolin Mfg. Co., Inc., 1100 Madison Ave., Montgomery 2, Ala.
(A,B,C) Nor-Lake, Inc., 2nd & Elm Sts., Hudson, Wis.
C. L. Percival Refrigerator Co., 1805 E. 4th St., Boone, Ia.
(A) Perfecold, Inc., 1940 S. Main St., Los Angeles 7, Cal.
(A,B,C) J. P. Pfeiffer & Son, Inc., 200 N. Paca St., Baltimore 1, Md.
(A,B) Puffer-Hubbard Mfg. Co., Grand Haven, Mich.
(B) Roessing Mfg. Co., Sharpsburg Sta., Pittsburgh, Pa
(A) W. Allen Rogers Industries, Inc., P.O. Box 272, Demopolis, Ala.
(A,B) C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
(B) Schwenger-Klein, Inc., 720 Bolivar Rd., Cleveland, O.
(A,B) Seeger Refrigerator Co., 850 Arcade St., St. Paul 6, Minn.
(A,B) Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
(A,B) Simplex Mfg. Co., 1135-3rd St., Oakland 20, Cal.
(A) Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
(B) Southern Fixture Mfg. Co., P.O. Box 245, Greensboro, N.C.
Stainless Food Equip. Co., 272 New St., Newark, N.J.
(B) Star Metal Mfg. Co., Trenton Ave. & Ann St., Phila. 34, Pa.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(B) Tyler Fixture Corp., 1401 Lake St., Niles, Mich. *(p. 80)*
(A,B) Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
(A,B) United Refrigerator Mfg. Co., Inc., 350 Robert St., St. Paul 1, Minn.
Viking Refrigerators, Inc., 7500 Wilson Ave., Kansas City 3, Mo.
Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.
(A,B) Warren Co., Inc., P.O. Box 1435, Atlanta 1, Ga.
(A,B,C) Weber Showcase & Fixture Co., Inc., P.O. Box 2018, Los Angeles 54, Cal.
Wilson Cabinet Co., Inc., Smyrna, Del.

REFRIGERATORS, RESTAURANT (See REFRIGERATORS, REACH-IN)

REFRIGERATORS—SALAD COUNTERS

Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Stanley Knight Corp., 3430 N. Pulaski Rd., Chicago 41, Ill.
John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
Stainless Food Equip. Co., 272 New St., Newark, N.J.
Star Metal Mfg. Co., Trenton Ave. & Ann St., Phila. 34 Pa.
Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.

REFRIGERATORS, SPECIAL

R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Bowser, Inc., Terryville, Ct.
Chapman & Wood Refrigeration, 4525 Southwest Pomona, Portland 19, Ore.
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
Foster Refrigerator Corp., Mill & 2nd St., Hudson, N.Y.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Gennett & Sons, Inc., 1 Main St., Richmond, Ind.
John Herrel & Sons Co.. 244 Lear St., Columbus 6, O.
Herrick Refrigerator Co., 1019 Commercial St., Waterloo, Ia. *(p. 170)*
Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 5, Mo. *(p. 81)*

Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
Marvel Industries, Inc., 14600 E. Seven Mile Rd., Detroit 5, Mich.
John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
Nor-Lake, Inc., 2nd & Elm Sts., Hudson, Wis.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Southern Fixture Co., P.O. Box 245, Greensboro, N.C.
Star Metal Mfg. Co., Inc., Trenton Ave. & Ann St., Phila. 34, Pa.
Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.

REGISTERS (See also GRILLES & AIR DIFFUSERS)

A & A Register Co., 8327 Clinton Rd., Cleveland 9, O.
A-J Mfg. Co., 2119 Washington, Kansas City 8, Mo.
Auer Register Co., 3608 Payne Ave., Cleveland, O.
Barber-Colman Co., Rockford, Ill.
Best Register Co., 2005 W. Oklahoma Ave., Milwaukee 7, Wis.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Hart & Cooley Mfg. Co., 500 E. 8th St., Holland, Mich.
Hastings Air Conditioning Co., Inc., Hastings, Neb.
Hendrick Mfg. Co., Carbondale, Pa.
Independent Register Co., 3747 E. 93rd St., Cleveland 5, O.
Lockjoint Wood Products Co., Wichita 7, Kan.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Pyle-Nat'l. Co., 1371 W. 37th St., Chicago 9, Ill.
Titus Mfg. Corp., Waterloo, Ia.
Tuttle & Bailey, Inc., New Britain, Ct
U. S. Register Co., 344 E. Burnham St., Battle Creek, Mich.

REGULATORS (See particular type following; also CONTROLS; also CONTROLLERS)

REGULATORS, CARBON DIOXIDE

Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
Dockson Corp., 3839 Wabash Ave., Detroit 8, Mich.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Hays Corp., Michigan City, Ind.
C. A. Norgren, 222 Santa Fe Drive, Denver, Col.
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.

REGULATORS, FLOW

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Fischer & Porter Co., Hatboro, Pa.
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Hays Corp., Michigan City, Ind.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Klipfel Valves, Inc., 1000 Weller Ave., Hamilton, O.
Leslie Co., Valley Brook & Grant Ave., Lyndhurst, N.J.
Moore Products Co., H & Lycoming Sts., Phila. 24, Pa.
Pittsburgh Equitable Meter Div., Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Refrigerating Specialties Co., 728 S. Sangamon Blvd., Chicago 12, Ill.
Trane Co., La Crosse, Wis. *(p. 12)*
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.

REGULATORS, LIQUID LEVEL (See CONTROLS, LIQUID LEVEL)

REGULATORS, PRESSURE

Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
A. W. Cash Co., 540 N. 18th St., Decatur, Ill.
Climax Engrg. Co., Controls Div., 15 N. Cincinnati, Tulsa, Okla.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Coral Designs, Box 248, Forest Hills, N.Y.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Davis Regulator Co., 2511 S. Washtenaw Ave., Chicago 8, Ill.
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Dockson Corp., 3839 Wabash Ave., Detroit 8, Mich.
Electric Sprayit Co., 1415 Illinois Ave., Sheboygan, Wis.
Erickson Specialty Co., 10 Cayuga St., Cohoes, N.Y.
Gas & Oil Industry Labs., Inc., 4 Paine Ave., Irvington 11, N.J.
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 12)*
Grove Regulator Co., 6529 Hollis St., Oakland, Cal.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Hays Corp., Michigan City, Ind.
Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Johnson Service Co., 507 E. Michigan St., Milwaukee 22, Wis.
O. C. Keckley Co., 400 W. Madison St., Chicago 6, Ill.
Klipfel Valves, Inc., 1000 Weller Ave., Hamilton, O.
Leslie Co., Valley Brook & Grant Ave., Lyndhurst, N.J.
Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 7, Minn. *(p. 70)*
Moore Products Co., H. & Lycoming Sts., Phila. 24, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
C. A. Norgren, 222 Santa Fe Drive, Denver, Colo.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
Schade Valve Mfg. Co., 2527 N. Bodine St., Phila. 33, Pa.
Sta-Rite Products, Inc., Delavan, Wis.
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. A. Thrush & Co., 21 E. Riverside Dr., Peru, Ind.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Watts Regulator Co., 10 Embankment St., Lawrence, Mass.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

REGULATORS, TEMPERATURE

American Schaeffer & Budenberg Instrument Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
Eastern Industries, Inc., 296 Elm St., New Haven 6, Ct.
Friez Instrument Div., Bendix Aviation Corp., Taylor Ave. at Loch Raven Blvd., Towson, Baltimore 4, Md.
Fulton Sylphon Co., Knoxville, Tenn.

(Continued)

REGULATORS, TEMPERATURE (Continued)

General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
Hays Corp., Michigan City, Ind.
Johnson Service Co., 507 E. Michigan St., Milwaukee 22, Wis.
O. C. Keckley Co., 400 W. Madison St., Chicago 6, Ill.
Klipfel Valves, Inc., 1000 Weller Ave., Hamilton, O.
Leslie Co., Valley Brook & Grant Ave., Lyndhurst, N.J.
Manning, Maxwell & Moore, Inc., Stratford, Ct.
Mason-Neilan Regulator Co., 1190 Adams St., Boston 24, Mass.
Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Moore Products Co., H. & Lycoming Sts., Phila. 24, Pa.
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Pyrometer Instrument Co., 103 Lafayette St., N.Y.C. 13
Ranco, Inc., 601 W. 5th Ave., Columbus 1, O. *(p. 69)*
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Sterling, Inc., 3738 N. Holton St., Milwaukee 12, Wis.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

REGULATORS, VOLTAGE

American Transformer Co., 172 Emmet St., Newark 5, N.J.
Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Electric Machinery Mfg. Co., 1338 Tyler St., N.E., Minneapolis 13, Minn.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Sola Elec. Co., 4633 W. 16th St., Chicago 50, Ill.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

RELAYS, ELECTRICAL (See also STARTERS)

Allen-Bradley Co., Milwaukee 4, Wis.
Automatic Switch Co., 391 Lakeside Ave., Orange, N.J.
Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Cook Elec. Co., 2700 Southport Ave., Chicago 14, Ill.
R. W. Cramer Co., P.O. Box 25, Centerbrook, Ct. *(p. 194)*
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
DuraKool, Inc., 1010 Main St., Elkhart, Ind.
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hart Mfg. Co., 110 Bartholomew Ave., Hartford 1, Ct.
Leach Relay Co., 5919 Avalon Blvd., Los Angeles 3, Cal.
Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Paragon Elec. Co., 1600-12th St., Two Rivers, Wis.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
Roller-Smith Div., Realty & Industrial Corp., Bethlehem, Pa.
Signal Engrg. & Mfg. Co., 154 W. 14th St., N.Y.C. 11
Spencer Thermostat Div. of Metals & Controls Corp. 34 Forest St., Attleboro, Mass.
Square D Co., Inc., 6060 Rivard St., Detroit 11, Mich.
Tork Clock Co., Inc., 1 Grove St., Mt. Vernon, N.Y.
Westinghouse Elec. Corp., Plane & Orange Sts., Newark 1, N.J.
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

RELIEF VALVES (See PRESSURE RELIEF VALVES)

RESINS, PLASTIC (See PLASTIC MOLDING COMPOUNDS)

RESISTORS, ELECTRICAL

Carborundum Co., P.O. Box 337, Niagara Falls, N.Y.
Clarostat Mfg. Co., Inc., 130 Clinton St., Brooklyn 2, N.Y.
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
I-T-E Circuit Breaker Co., 19th & Hamilton Sts., Phila. 30, Pa.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls. Ind.
Ohio Carbon Co., 12508 Berea Rd., Cleveland 11, O.
Ohmite Mfg. Co., 4835 W. Flournoy St., Chicago 44, Ill.
Sprague Products Co., Marshall St., N. Adams, Mass.
Westinghouse Elec. Corp., 4454 Genesee St., Buffalo 5, N.Y.
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.
Edwin L. Wiegand Co., 7506 Thomas Blvd., Pittsburgh 8, Pa.

RESPIRATORS (See GAS MASKS)

RETARDERS, CORROSION (See INHIBITORS)

RETARDERS, DOUGH (See DOUGH RETARDERS)

RETURN BENDS

Acme Equip. Co., 205 E. B'way, Muskogee, Okla.
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Fitzsimons Mfg., 3775 E. Outer Dr., Detroit 12, Mich.
Grabler Mfg. Co., 6565 Broadway, Cleveland 5, O.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Henry Valve Co., Melrose Park, Ill. *(p. 102)*
Lul Products, Inc., 2235 Sisson St., Baltimore 11, Md.
C. F. Moores Co., 1123 Ivy Hill Rd., Wyndmoor, Phila. 18, Pa.
Mueller Brass Co., Port Huron, Mich.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Taylor Forge & Pipe Wks., P.O. Box 485, Chicago 90, Ill.
Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
Tube-Turns, Inc., 224 E. Broadway, Louisville 1, Ky.
Walworth Co., 60 E. 42nd St., N.Y.C. 17

REVOLUTION COUNTERS (See COUNTING & COMPUTING DEVICES)

RHEOSTATS

Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
Ohmite Mfg. Co., 4835 W. Flournoy St., Chicago 44, Ill.
Vulcan Elec. Co., 88 Holton St., Danvers, Mass.
Westinghouse Elec. Co., 4454 Genesee St., Buffalo 5, N.Y

RINGS, LUBRICANT RETAINER

Graphite Metallizing Corp., 1013 Nepperhan Ave., Yonkers 3, N.Y.
Messinger Bearings, Inc., D St. above Erie Ave., Phila. 1, Pa.

RINGS, PIPE WELDING

All-State Welding Alloys Co., Inc., 273 Ferris Ave., White Plains, N.Y.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

Sarco Company, Inc.

Branches in Principal Cities

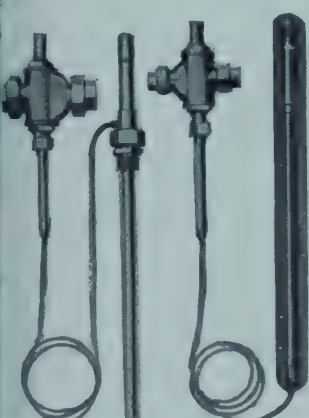
Empire State Building **New York 1, N.Y.**

SARCO CANADA LIMITED, 496 Church St., Toronto 5, Ont., Canada

AIR CONDITIONING ACCESSORIES

Sarco products have kept pace with the rapid developments in Air Conditioning. Two types of temperature control, blenders for controlling brine flow, steam traps and strainers are available in a complete range of sizes.

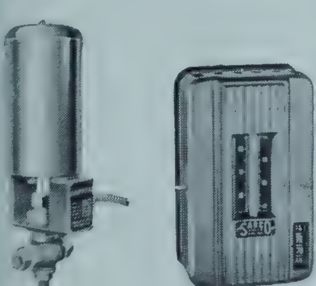
SELF-CONTAINED TEMPERATURE REGULATORS



Type TR-21 Type KR-14

For ducts, reheaters, drinking water control, unit coolers and brine coils. They are simple, self-operated valves—using the irresistible force of liquid expansion. No stuffing boxes to leak, no auxiliary "power" required; all moving parts are *inside* the equipment. A type and size for every purpose—for steam, gas, oil, water or brine, for temperatures ranging from 0 to 300° F. Catalog No. RD600.

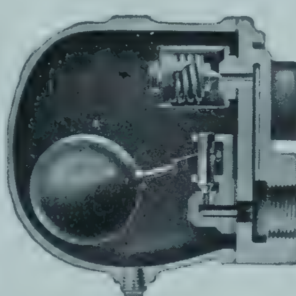
ELECTRIC CONTROLS



Motor Valve Thermostat

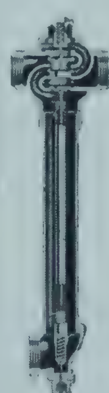
For refrigeration and air conditioning. When temperature control must be close, when wide and rapid fluctuations must be corrected instantly, when the thermostat is at a distance from the controlled unit, use electric regulators. They consist of room thermostats, aquastats, and limit controls for all heating and air conditioning needs; also motor valves for steam, water, brine or Freon. Catalog No. RD1000.

FLOAT-THERMOSTATIC TRAPS



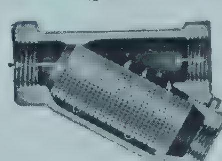
For blast coils, dripping ends of mains and risers, and for stack or blast heaters, large unit heaters and hot water generators. Automatic thermostatic air vents built in. Available in six sizes with connections ¾ to 2 in. Catalog No. RD450.

BLENDERS



For mixing warm and cold brine or water for cooling coils and unit coolers. Also mix very hot and cold water and deliver blended water at any temperature for which they have been adjusted. Valves are fully balanced so that control is not disturbed by differing or fluctuating water or brine pressures. Available in sizes ½ in. to 4 in., for pressures up to 150 lb. Catalog Nos. RD700 and RD800.

SELF-CLEANING STRAINERS



For use in pipe lines carrying brine, steam, oil, gas, water, ammonia or air. Have large free screening area with minimum resistance to flow. Steam or air strainers can be cleaned by blowing through without disassembling. Made in cast iron, bronze or cast steel for pressures up to 500 lbs., with brass, iron or monel screens. Available in sizes ¼ to 8 in. Catalog No. RD1200.

RINGS, RUBBER, FOR REFRIGERATED FIXTURES

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
Ball Bros. Co., Muncie, Ind.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber)

RIVET TREATING CABINETS (See REFRIGERATORS, LOW TEMPERATURE)

RIVETS

Aluminum Co. of America, Pittsburgh 19, Pa.
W. Ames & Co., Jersey City, N.J.
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Bethlehem Steel Co., Bethlehem, Pa.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Cherry Rivet Co., 231 Winston St., Los Angeles 13, Cal.
Clark Bros. Bolt Co., Milldale, Ct.
Crescent Belt Fastener Co., 480 Lexington Ave., N.Y.C. 17
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del. (Explosive)
Fansteel Metallurgical Corp., N. Chicago, Ill. (Contact)
General Plate Div., Metals & Controls Corp., Attleboro, Mass. (Precious Metals)
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind. (Precious Metals)
Oliver Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Townsend Co., 205 River Rd., New Brighton, Pa.

ROD, ALUMINUM

Aluminum Co. of America, Pittsburgh 19, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32 Ill.
Colonial Alloys Co., Ridge Ave. & Crawford St., Phila. 29, Pa.
Mueller Brass Co., Port Huron, Mich.
Permanente Products Co., 1924 Broadway, Oakland 12, Cal.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.

ROD, BRASS, BRONZE & COPPER

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Bristol Brass Corp., Bristol, Ct.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
C. G. Hussey & Co., 2860-2nd Ave., Pittsburgh 19, Pa.
Lewin-Mathes Co., 1111 Chouteau, St. Louis, Mo.
Mueller Brass Co., Port Huron, Mich.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Titan Metal Mfg. Co., Bellefonte, Pa.

ROD, DRILL

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Bethlehem Steel Co., Bethlehem, Pa.
Carpenter Steel Co., Reading, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Vanadium-Alloys Steel Co., Latrobe, Pa.

ROD, NICKEL & NICKEL ALLOY

Carpenter Steel Co., Reading, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
International Nickel Co., 67 Wall St., N.Y.C.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.

ROD, STEEL

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Firth-Sterling Steel & Carbide Corp., Demmler Rd., McKeesport, Pa.

ROD, STEEL, STAINLESS

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Arcos Corp., 1515 Locust St., Phila. 2, Pa.
Bethlehem Steel Co., Bethlehem, Pa.
Carpenter Steel Co., Reading, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Firth-Sterling Steel & Carbide Corp., Demmler Rd., McKeesport, Pa.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.

ROD, THREADED & TIE

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Autoscrew Co,. 216 W. 18th St., N.Y.C. 11
Bethlehem Steel Co., Bethlehem, Pa.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Columbus Bolt Wks. Co., 291 Marconi Blvd., Columbus 16, O.
Eastern Machine Screw Corp., Truman & Barclay Sts., New Haven, Ct.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 51, Mo.

ROLLERS, RUBBER

Bushings, Inc., 4358 Coolidge Highwy., Royal Oak, Mich.
Dayton Rubber Mfg. Co., 2342 W. Riverview Ave., Dayton 1, O.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos Manhattan, Inc., 61 Willett St., Passaic, N.J.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber)

ROLLERS, SLIDING DOOR

Knape & Vogt Mfg. Co., Grand Rapids 4, Mich.
Standard-Keil Hardware Mfg. Co., Inc., 639 B'way N.Y.C. 12

ROOF COOLING, SYSTEMS

April Showers Co., 4126-8th St., N.W., Washington 11, D.C. *(p. 175)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Siegfried Ruppright, Box 6795, Los Angeles 22, Cal.
Spraying Systems Co., 3201 Randolph St., Bellwood, Chicago, Ill.
Water Cooling Corp., 71Nassau St., N.Y.C. 7
Water Cooling Equip. Corp., Afton Sta., St. Louis 23, Mo.

ROOM COOLERS (See AIR CONDITIONERS)

RUBBER, SYNTHETIC, & RUBBER-LIKE PLASTICS

Canfield Rubber Co., 708 Railroad Ave., Bridgeport 5, Ct.
Continental Rubber Wks., 2000 Liberty St., Erie, Pa.
Dennis Chemical Co., 2701 Papin St., St. Louis 3, Mo.
E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Del.
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Goshen Rubber & Mfg. Co., Box 417, Goshen, Ind.
Haveg Corp., Marshallton, Del.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Inland Mfg. Div., Gen'l Motors Corp., Dayton 1, O.
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
Mack Molding Co., Ryerson Ave., Wayne, N.J.
National Motor Bearing Co., Inc., Redwood City, Cal.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Presstite Engrg. Co., 3900 Chouteau Ave., St. Louis 10, Mo.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Thermoid Co., Trenton, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.
S. S. White Dental Mfg. Co., 10 E. 40th St., N.Y.C.
Franklin C. Wolfe Co., 407 Commercial Center St., Beverly Hills, Cal.

RUBBER PRODUCTS, CELLULAR

Dayton Rubber Mfg. Co., 2342 W. Riverview Ave., Dayton 1, O.
Dryden Rubber Co., 1014 S. Kildare Ave., Chicago 24, Ill.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Robinson Aviation, Inc., Teterboro, N.J.
Rubatex Div., Great American Industries, Bedford, Va. *(p. 137)*
Sponge Rubber Products Co., Howe Ave., Shelton, Ct.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.

RUBBER PRODUCTS, EXTRUDED

Ball Bros. Co., Muncie, Ind.
Canfield Rubber Co., 708 Railroad Ave., Bridgeport 5, Ct.
Continental Rubber Wks., 2000 Liberty St., Erie, Pa.
Dryden Rubber Co., 1014 S. Kildare Ave., Chicago 24, Ill.
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Jarrow Products, 420 N. La Salle St., Chicago 10, Ill. *(p. 83)*
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
National Motor Bearing Co., Inc., Redwood City, Cal.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.

RUBBER PRODUCTS, HARD

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Luzerne Rubber Co., Trenton 9, N.J.
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J.
Thermoid Co., Trenton, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.

RUBBER PRODUCTS, MECHANICAL BONDED

Apex Molded Products Co., 3574 Ruth St., Phila. 34, Pa.
Bushings, Inc., 4358 Coolidge Highwy., Royal Oak, Mich.
Dryden Rubber Co., 1014 S. Kildare Ave., Chicago 24, Ill.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.

(Continued)

RUBBER PRODUCTS, MECHANICAL BONDED (Continued)

B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
Lord Mfg. Co., 1635 W. 12th St., Erie, Pa.
National Motor Bearing Co., Inc., Redwood City, Cal.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.
Franklin C. Wolfe Co., 407 Commercial Center St., Beverly Hills, Cal.

RUBBER PRODUCTS, MOLDED

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
Apex Molded Products Co., 3574 Ruth St. 34, Phila. Pa.,
Ball Bros. Co., Muncie, Ind.
Canfield Rubber Co., 708 Railroad Ave., Bridgeport 5, Ct.
Continental Rubber Wks., 2000 Liberty St., Erie, Pa.
Darcoid Co., Inc., 145-6th Ave., N.Y.C. 13
Dryden Rubber Co., 1014 S. Kildare Ave., Chicago 24, Ill
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
Garlock Packing Co., 402 E. Main St., Palymra, N.Y.
Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
National Motor Bearing Co., Inc., Redwood City, Cal.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Robinson Aviation, Inc., Teterboro, N.J.
Sponge Rubber Products Co., Howe Ave., Shelton, Ct.
Standard Products Co., 505 Blvd., Bldg., Detroit 2, Mich.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J.
Thermoid Co., Trenton, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.
Franklin C. Wolfe Co., 407 Commercial Center St., Beverly Hills, Cal.

RUPTURE MEMBERS (See PRESSURE RELIEF DEVICES)

SADDLES, PIPE (See FITTINGS; also HANGERS, PIPE)

SAFETY SHUT-OFFS FOR GAS REFRIGERATORS

Spencer Thermostat Div., Metals & Controls Corp. 34 Forest St., Attleboro, Mass.

SAFETY VALVES (See PRESSURE RELIEF VALVES)

SALAD REFRIGERATORS (See REFRIGERATORS, SALAD)

SCALE INHIBITORS (See INHIBITORS)

SCALE TRAPS (See also STRAINERS; also FILTERS, etc.)

Dersch, Gesswein & Nevert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Henry Valve Co., Melrose Park, Ill. *(p. 187)*
Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
Neptune Meter Co., 50 W. 50th St., N.Y.C. 20
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

SCREENS, PERFORATED METAL (See METAL, PERFORATED)

SCREENS, SPECIAL

Hendrick Mfg. Co., Carbondale, Pa.
Industrial Wire Cloth Products Corp., Wayne), Mich. *(p. 85)*
McIntire Connector Co., 252 Jefferson St., Newark 5, N.J. *(p. 84)*
Newark Wire Cloth, 351 Verona Ave., Newark 4, N.J.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Robins Conveyors Div., Hewitt-Robins, Inc., Passaic, N.J.

SCREENS, VIBRATING

Deister Concentrator Co., 901 Glasgow Ave., Ft. Wayne, Ind.
Hendrick Mfg. Co., Carbondale, Pa.
Link-Belt Co., 2045 W. Hunting Park, Phila. 40, Pa.
D. V. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
Read Machinery Div., Standard Stoker Co., Inc., York, Pa.
Robins Conveyors Div., Hewitt-Robins, Inc., Passaic, N.J.

SCREENS, WIRE (See also WIRE CLOTH)

Cambridge Wire Cloth Co., Cambridge, Md.
Central Wire & Iron Wks., 621 E. Locust St., Des Moines 9, Ia.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Cyclone Fence Div., American Steel & Wire Co., U. S. Steel Corp. Subsidiary, P.O. Box 260, Waukegan 1, Ill.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Jeffrey Mfg. Co., 887 N. 4th St., Columbus 16, O.
Kenmore Machine Products, Inc., 15 Depew Ave., Lyons, N.Y.
Michigan Wire Cloth Co., 2098 Howard St., Detroit 16, Mich.
Newark Wire Cloth, 351 Verona Ave., Newark 4, N.J.
Robins Conveyors Div., Hewitt-Robins, Inc., Passaic, N.J.

SCREW MACHINE PARTS (See also THREADED SPECIALTIES)

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Cleveland Cap Screw Co., 2917 E. 79th St., Cleveland 4, O.
Corbin Screw Corp., New Britain, Ct.
Delavan Mfg. Co., 3009-6th Ave., Des Moines 13, Ia.
Eastern Machine Screw Corp., Truman & Barclay Sts., New Haven 6, Ct.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Mueller Brass Co., Port Huron, Mich.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Townsend Co., 205 River Rd., New Brighton, Pa.

SCREWS, CAP, MACHINE, etc.

Allen Mfg. Co., 135 Sheldon St., Hartford 5, Ct.

(Continued)

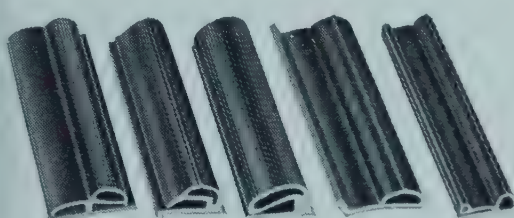
THE GENERAL TIRE & RUBBER CO.

MAKERS OF AMERICA'S TOP QUALITY TIRE

Mechanical Goods Division • Wabash, Indiana

GENERAL *Engineered Rubber Parts*

Rubber parts for refrigerating and air-conditioning equipment, made to your specification and General quality standards. General engineers offer skilled help in selecting the right rubber and design for top efficiency.

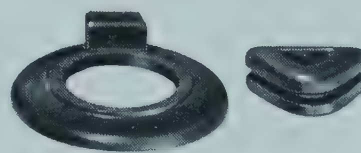


RUBBER DOOR GASKETS

Extruded rubber gaskets in any design and size, solid or hollow, made accurately to specification. Natural or synthetic rubber. Our method of compounding produces gaskets that are odorless, tasteless and non-staining, with excellent compressibility. Shown above are gaskets supplied by us to leading refrigerator makers.

BONDED-TO-METAL PARTS

General is experienced in making rubber-bonded-to-metal parts of all kinds—hard and soft rubber knobs, cooler lids, fountain fittings, bumpers, and other parts.



MOLDED RUBBER PARTS

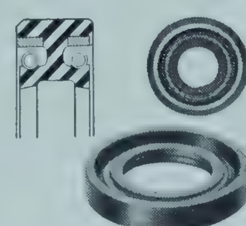
General is equipped to supply all types of molded rubber parts in any size and design, made to specification, of hard and soft rubber. Dust seal and rubber bushing shown are typical of many refrigerator parts molded by General.

DIE-CUT RUBBER PARTS

General is a reliable source of supply for die-cut rubber parts—washers, gaskets, etc. Made to your specification, to close tolerances.

OIL AND REFRIGERANT SEALS

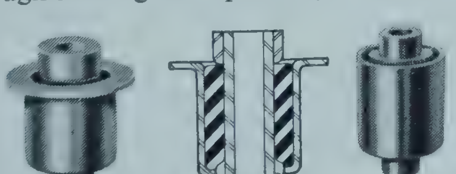
Shown are single and double-lip oil seals designed by General for highest efficiency and service. General engineers can help you design seals for lubricants and refrigerants to meet your special needs.



Precision Vibration Control with

GENERAL SILENTBLOC MOUNTINGS

GENERAL Silentbloc Mountings offer precision control of vibration and noise in motors, compressors, fans and pumps. Engineered to conform to any curve of deflection, they give complete control of vibration through starting and operating cycles. Silentbloc performance is due to its patented construction—elongation and confinement of rubber between metal sleeves. Radial compressive force, with even distribution of stress, assures indestructible rubber-to-metal adhesion and long service.



Silentbloc Mountings can solve your problems of vibration and noise in domestic and commercial equipment. Made of any metal, in any size to carry loads of ounces to tons. Simple to incorporate in your designs, easy to install. Write for Silentbloc booklet.

SCREWS, CAP, MACHINE, etc. (Continued)

Allmetal Screw Products Co., Inc., 22 Greene St., N.Y.C. 13
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Bristol Co., Waterbury 91, Ct.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago Screw Co., 2701 Washington Blvd., Bellwood, Ill.
Clark Bros. Bolt Co., Milldale, Ct.
Cleveland Cap Screw Co., 2917 E. 79th St., Cleveland 4, O.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
Corbin Screw Corp., New Britain, Ct.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Wm. H. Haskell Mfg. Co., 24 Commerce St., Pawtucket, R.I.
Holo-Krome Screw Corp., 25 Brook St., Hartford 10, Ct.
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Standard Pressed Steel Co., Jenkintown, Pa.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

SCREWS, DRIVE

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
American Screw Co., 21 Stevens, Providence 1, R.I.
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Townsend Co., 205 River Rd., New Brighton, Pa.

SCREWS, LAG

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Bethlehem Steel Co., Bethlehem, Pa.
Boss Nut & Bolt Co., 3403 W. 47th St., Chicago, Ill.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Corbin Screw Corp., New Britain, Ct.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Oliver Iron & Steel Corp., S. 10th & Muriel Sts., Pittsburgh 3, Pa.
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Star Expansion Bolt Co., 147 Cedar St., N.Y.C. 6

Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

SCREW, LOCK; LOCKING; LOCK WASHER

American Screw Co., 21 Stevens, Providence 1, R.I.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Shakeproof, Inc., 2401 N. Keeler Ave., Chicago 39, Ill.
Standard Pressed Steel Co., Jenkintown, Pa.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

SCREWS, PHILLIPS HEAD

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
American Screw Co., 21 Stevens, Providence 1, R.I.
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

SCREWS, SELF-TAPPING, SHEET METAL, etc.

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
American Screw Co., 21 Stevens, Providence 1, R.I.
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
Corbin Screw Corp., New Britain, Ct.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
Shakeproof, Inc., 2501 N. Keeler Ave., Chicago 39, Ill.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Townsend Co., 205 River Rd., New Brighton, Pa.

SCREWS, SET

Allen Mfg. Co., 135 Sheldon St., Hartford 5, Ct.
Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Bethlehem Steel Co., Bethlehem, Pa.
Bristol Co., Waterbury 91, Ct.
Chicago Screw Co., 2701 Washington Blvd., Bellwood, Ill.
Clark Bros. Bolt Co., Milldale, Ct.
Cleveland Cap Screw Co., 2917 E. 79th St., Cleveland 4, O.
Corbin Screw Corp., New Britain, Ct.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Holo-Krome Screw Corp., 10 Brook St., Hartford 10, Ct.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
William H. Ottemiller Co., Pattison St. & M&P R.R., York, Pa.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.

Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Standard Pressed Steel Co., Jenkintown, Pa.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Triplex Screw Co., 5317 Grant Ave., Cleveland 4, O.

SCREWS, SPECIAL

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
American Screw Co., 21 Stevens, Providence 1, R.I.
Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Bethlehem Steel Co., Bethlehem, Pa.
Bristol Co., Waterbury 91, Ct.
Buffalo Bolt Co., 101 East Ave., N. Tonawanda, N.Y.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Chicago Screw Co., 2701 Washington Blvd., Bellwood, Ill.
Clark Bros. Bolt Co., Milldale, Ct.
Cleveland Cap Screw Co., 2917 E. 79th St., Cleveland 4, O.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Mound Tool Co., 1203 S. 7th St., St. Louis 4, Mo.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Russell, Burdsall & Ward Bolt & Nut Co., Port Chester, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Standard Pressed Steel Co., Jenkintown, Pa.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Townsend Co., 205 River Rd., New Brighton, Pa.

SCREWS, THUMB

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Ohio Nut & Bolt Co., 600 Front St., Berea, O.
Parker-Kalon Corp., 200 Varick St., N.Y.C. 14
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Stronghold Screw Products, Inc., 216 W. Hubbard St. Chicago 10, Ill.
Townsend Co., 205 River Rd., New Brighton, Pa.
J. H. Williams & Co., 400 Vulcan St., Buffalo 7, N.Y.

SCREWS, WELD

Atlas Bolt & Screw Co., 1108 Ivanhoe Rd., Cleveland 10, O.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Ohio Nut & Bolt Co., 600 Front St., Berea, O.
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

SCREWS, WOOD

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
American Screw Co., 21 Stevens, Providence 1, R.I.
Central Screw Co., 3501 Shields Ave., Chicago 9, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Pheoll Mfg. Co., 5700 Roosevelt Rd., Chicago 50, Ill.
Rockford Screw Products Co., 2501-9th St., Rockford, Ill.
Star Expansion Bolt Co., 147 Cedar St., N.Y.C. 6
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.

SCROLLS, BLOWER (See **BLOWERS, WHEELS, HOUSINGS**)

SCUTTLE BUTTS (See **DRINKING WATER COOLERS**)

SEALING COMPOUNDS (See **COMPOUNDS**)

SEALS, DOOR BOTTOM (See also **DOOR GASKETS**)

Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
W. J. Dennis & Co., 1732 N. Kolmar Ave., Chicago 39, Ill.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Jarrow Products, 420 N. La Salle St., Chicago 10, Ill. *(p. 83)*
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Franklin C. Wolfe Co., 407 Commercial Center St., Beverly Hills, Cal.

SEALS, OIL

Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
National Motor Bearing Co., Inc., Redwood City, Cal.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Victor Mfg. & Gasket Co., 5750 Roosevelt Rd., Chicago 90, Ill.
Franklin C. Wolfe Co., 407 Commercial Center St., Beverly Hills, Cal.

SEALS, RUBBER

Apex Molded Products Co., 3574 Ruth St., Phila. 34, Pa.
Ball Bros. Co., Muncie, Ind.
Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind. ("O" Ring)
Inland Mfg. Div., Gen'l. Motors Corp., Dayton 1, O.
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
National Motor Bearing Co., Inc., Redwood City, Cal.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Pacific States Felt & Mfg. Co., Inc., 843 Howard St., San Francisco 3, Cal.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Rubatex Div., Great American Industries, Bedford, Va. *(p. 137)*
Sponge Rubber Products Co., Howe Ave., Shelton, Ct.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Franklin C. Wolfe Co., 407 Commercial Center St., Beverly Hills, Cal.

SEALS, SHAFT (See also **PACKING**)

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Bearium Metals Corp., 268 State St., Rochester, N.Y.
Bridgeport Thermostat Co., Inc., 1225 Connecticut Ave., Bridgeport 1, Ct.
Chicago Seal Co., 232 S. Hoyne Ave., Chicago 20, Ill.
Clifford Mfg. Co., 110 Grove St., Waltham 54, Mass. *(p. 27)*
Crane Packing Co., 1800 Cuyler Ave., Chicago 13, Ill.
Durametallic Corp., 2104 Factory St., Kalamazoo 24F, Mich.
Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Linear, Inc., State Rd. & Levick St., Phila. 35, Pa.
National Motor Bearing Co., Inc., Redwood City, Cal.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Rotary Seal Co., 2020 N. Larrabee St., Chicago 14, Ill.
Speer Carbon Co., St. Marys, Pa.
U. S. Graphite Co., Saginaw, Mich.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Victor Mfg. & Gasket Co., 5750 Roosevelt Rd., Chicago 90, Ill.

SEAMLESS TUBING (See TUBES & TUBING)

SEATS, COMPRESSOR VALVE

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Chicago Seal Co., 232 S. Hoyne Ave., Chicago 20, Ill.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. (p. *29*)

SELF-SERVICE REFRIGERATORS (See DISPLAY CASES)

SEPARATORS (See particular type, i.e., OIL; also STEAM, etc.)

SHAFTS & SHAFTING

Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Link-Belt Co., 519 Holmes Ave., Indpls. 6, Ind.
Modern Machine Wks., Inc., 5350 S. Kirkwood Ave., Cudahy, Wis. (*p. 180*)
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Spicer Mfg. Co., 4100 Bennett Rd., Toledo 1, O.

SHAFT COUPLINGS (See also FLEXIBLE COUPLINGS)

Ajax Flexible Coupling Co., Inc., Westfield, N.Y.
Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
American Flexible Coupling Co., 1808 Pittsburgh Ave., Erie, Pa.
Charles Bond Co., 617-23 Arch St., Phila., Pa.
Bond Foundry & Machine Co., Manheim, Pa.
Bushings, Inc., 4358 Coolidge Highwy., Royal Oak, Mich.
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
Centric Clutch Co., 23 South Ave., W. Crawford, N.J.
Chicago Die Casting Mfg. Co., 2500 W. Monroe St., Chicago 12, Ill.
Congress Drive Div., Tann Corp., 3750 E. Outer Drive, Detroit 34, Mich.
Continental Diamond Fibre Co., 3 Chapel St., Newark, Del.
Crocker-Wheeler Div., Joshua Hendy Iron Wks., Ampere, N.J. (Flexible)
Diamond Chain Co., Inc., 402 Kentucky Ave., Indpls. 7, Ind.
Jeffrey Mfg. Co., 887 N. 4th St., Columbus 16, O.
W. A. Jones Foundry & Machine Co., 4401 Roosevelt Rd., Chicago 24, Ill.
Link-Belt Co., 220 S. Belmont Ave., Indpls. 6, Ind.
Link-Belt Co., 519 Holmes Ave., Indpls. 6, Ind.
Lord Mfg. Co., 1635 W. 12th St., Erie, Pa.
Morse Chain Co., Div. of Borg-Warner Corp., Ithaca, N.Y.
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Palmer-Bee Co., 1701 Poland Ave., Detroit 12, Mich.
Ramsey Chain Co., Inc., 900 Broadway, Albany 1, N.Y.
Simonds Gear & Mfg. Co., 2501 Liberty Ave., Pittsburgh 22, Pa.
Twin Disc Clutch Co., Racine, Wis.
J. A. Zurn Mfg. Co., Erie, Pa.

SHAFT SEALS (See SEALS)

SHAPES, ALUMINUM

Aluminum Co. of America, Pittsburgh 19, Pa.
Bohn Aluminum & Brass Corp., E. Maumee, Adrian, Mich.
Brasco Mfg. Co., Harvey, Ill.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Charles W. Krieg Co., 48 Dickerson St., Newark 4, N.J.
Melrath Supply & Gasket Co., Inc., Tioga & Memphis Sts., Phila. 34, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 (*p. 197*)
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.

SHAPES, BRASS, BRONZE & COPPER

American Brass Co., Waterbury 88, Ct. (*p. 199*)
Bohn Aluminum R Brass Corp, E. Maumee, Adrian, Mich.
Brasco Mfg. Co., Harvey, Ill.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Charles W. Krieg Co., 48 Dickerson St., Newark 4, N.J.
Melrath Supply & Gasket Co., Inc., Tioga & Memphis Sts., Phila. 34, Pa.
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 (*p. 197*)
Titan Metal Mfg. Co., Bellefonte, Pa.

SHAPES, DRAWN OR PRESSED (See Also STAMPINGS; also SHELLS)

Ackermann Mfg. Co., Wheeling, W. Va.
Acklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. (*p. 185*)
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. (*p. 29*)
Fitzsimons Mfg. Co., 3775 E. Outer Dr., Detroit 12, Mich.
L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Heintz Mfg. Co., Front St. & Olney Ave., Phila. 20, Pa.
Charles W. Krieg Co., 48 Dickerson St., Newark 4, N.J.
Lansing Stamping Co., 1159 S. Pennsylvania Ave., Lansing 2, Mich.
Linde Air Products Co., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Powell Pressed Steel Co., Hubbard, O.
Pressed Steel Tank Co., 1471 S. 66th St., Milwaukee 14, Wis. (*p. 77*)
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 (*p. 197*)
Stanley Wks., 195 Lake St., New Britain, Ct.
Toledo Stamping & Mfg. Co., 99 Fearing Blvd., Toledo 7, O.

SHAPES, EXTRUDED

American Brass Co., Waterbury 88, Ct. (*p. 199*)
Bohn Aluminum & Brass Corp., E. Maumee, Adrian, Mich.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Continental Rubber Wks., 2000 Liberty St., Erie, Pa.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 (*p. 197*)
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.

Sandee Mfg. Co., 5050 W. Foster Ave., Chicago 30, Ill.
Titan Metal Mfg. Co., Bellefonte, Pa.
R. D. Werner Co., Inc., 295-5th Ave., N.Y.C. 16

SHAPES, STRUCTURAL

Atlantic Steel Co., P.O. Box 1714, Atlanta, Ga.
Bethlehem Steel Co., Bethlehem, Pa.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
Brasco Mfg. Co., Harvey, Ill.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Jones & Laughlin Steel Co., Pittsburgh, Pa.
Laclede Steel Co., Arcade Bldg., St. Louis 1, Mo.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.
Weirton Steel Co., Weirton, W. Va.

SHAPES, VULCANIZED FIBRE (See FIBRE)

SHARP FREEZERS (See FREEZERS)

SHEAVES (See PULLEYS)

SHEET METAL ASSEMBLY & MANUFACTURING

Burt Mfg. Co., 932 S. High St., Akron 11, O.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Erie Art Metal Co., 1602 E. 18 St., Erie, Pa. (Parts)
Evans Mfg. Co., 460 S. 10th Ave., Mt. Vernon, N.Y.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
Mullins Mfg. Corp., S. Ellsworth St., Salem, O.
New York Iron Roofing & Corrugating Co., Inc., 94-1st St., Jersey City 2, N.J.
R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Robinson Aviation, Inc., Teterboro, N.J.
Stanley Wks., 195 Lake St., New Britain, Ct.
Wirt & Knox Mfg. Co., 23rd & York Sts., Phila. 32, Pa.

SHEET, ALLOY

Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Henry Disston & Sons, Inc., Tacony, Phila. 35, Pa.
Illinois Zinc Co., 2959 W. 47th St., Chicago 32, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.

SHEET, ALUMINUM

Aluminum Co. of America, Pittsburgh 19, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Fairmount Aluminum Co., Fairmount, W. Va.
Permanente Products Co., 1924 Broadway, Oakland 12, Cal.
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.
Rigidized Metals Corp., 658 Ohio St., Buffalo 3, N.Y.
United Smelting & Aluminum Co., Inc., New Haven, Ct.

SHEET, ASBESTOS

Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17 *(p. 135)*
Belmont Packing & Rubber Co., Butler & Sepviva Sts., Phila. 7, Pa.
Philip Carey Mfg. Co., Lockland Cin'ti. 15, O.
Darcoid Co., Inc., 145-6th Ave., N.Y.C. 13
Durabla Mfg. Co., 114 Liberty St., N.Y.C. 6
Ehret Magnesia Mfg. Co., Valley Forge, Pa.
Felt Products Mfg. Co., 1508 W. Carroll Ave., Chicago 7, Ill.
Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
Hollow Center Packing Co., 6523 Euclid Ave., Cleveland 3, O.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Keasbey & Mattison Co., Ambler, Pa.
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
Linear, Inc., State Rd., & Levick St., Phila. 35, Pa.
Melrath Supply & Gasket Co., Inc., Tioga & Memphis Sts., Phila. 34, Pa.
Norristown Magnesia & Asbestos Co., Washington St. below Ford St., Norristown, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J
Ruberoid Co., 500-5th Ave., N.Y.C. 18
Rutland Fire Clay Co., Curtis Ave., Rutland, Vt.
Standard Asbestos Mfg. Co., 860 W. Evergreen Ave., Chicago 22, Ill.
Victor Mfg. & Gasket Co., 5750 Roosevelt Rd., Chicago 90, Ill.
Grant Wilson, Inc., 316 S. La Salle St., Chicago 4, Ill.

SHEET, BRASS, BRONZE, COPPER

American Brass Co., Waterbury, Ct. *(p. 199)*
Bristol Brass Corp., Bristol, Ct.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
C. G. Hussey & Co., 2860-2nd Ave., Pittsburgh 19, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
SisalKraft Co., 205 W. Wacker Drive, Chicago 6, Ill.
Western Brass Mills, Div. of Olin Industries, Inc., E. Alton, Ill.

SHEET, ENAMELING

Armco Steel Corp., Middletown, O.
Berger Mfg. Div., Republic Steel Corp., 1038 Belden Ave., N.E., Canton 5, O.
Carnegie-Illinois Steel Corp., U. S. Steel Corp., Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 300 W. 51st St., Chicago 32, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Rigidized Metals Corp., 658 Ohio St., Buffalo 3, N.Y.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.

SHEET, INCONEL, MONEL & NICKEL

International Nickel Co., 67 Wall St., N.Y.C. 5

SHEET, STEEL (See also particular type)

Armco Steel Corp., Middletown, O.
Bethlehem Steel Co., Bethlehem, Pa.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Inland Steel Co., 38 S. Dearborn St., Chicago 13, Ill.
Jones & Laughlin Steel Co., Pittsburgh, Pa.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.
Weirton Steel Co., Weirton, W. Va.
Wheeling Corrugating Co., Wheeling, W. Va.
Wheeling Steel Corp., Wheeling, W. Va.
Youngstown Sheet & Tube Co., Youngstown, O.

SHEET, STEEL, COATED OR GALVANIZED

Armco Steel Corp., Middletown, O.
Berger Mfg. Div., Republic Steel Corp., 1038 Belden Ave., N.E., Canton 5, O.
Bethlehem Steel Co., Bethlehem, Pa.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
Jones & Laughlin Steel Co., Pittsburgh, Pa.
A. B. Murray Co., Inc., 630 Greene Lane, Elizabeth, N.J.
National Lead Co., 111 Broadway, N.Y.C. 6
New York Iron Roofing & Corrugating Co., Inc., 94-1st St., Jersey City 2, N.J.
Reeves Steel & Mfg. Co., 137 E. Iron Ave., Dover, O.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Weirton Steel Co., Weirton, W. Va.
Wheeling Corrugating Co., Wheeling, W. Va.
Wheeling Steel Corp., Wheeling, W. Va.

SHEET, STEEL, ELECTRICAL

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Armco Steel Corp., Middletown, O.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.
Wheeling Steel Corp., Wheeling, W. Va.

SHEET, STEEL, STAINLESS

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Armco Steel Corp., Middletown, O.
Berger Mfg. Div., Republic Steel Corp., 1038 Belden Ave., N.E., Canton 5, O.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Eastern Stainless Steel Corp., P.O. Box 1975, Baltimore 3, Md.
Goettl Bros. Metal Products, Inc., 714 S. Central, Phoenix, Ariz.
New York Iron Roofing & Corrugating Co., Inc., 94-1st St., Jersey City 2, N.J.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Rigidized Metals Corp., 658 Ohio St., Buffalo 3, N.Y.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.

SHEET, ZINC

New Jersey Zinc Co., 160 Front St., N.Y.C. 7

SHELLS, DRAWN OR SEAMLESS (See SHAPES, DRAWN)

SHELVES, REFRIGERATOR (See also RACKS; also WIRE FORMING)

Collis Co., Box 231, Clinton, Ia.
Dearborn Glass Co., 2414 W. 21st St., Chicago 8, Ill.
Hoosier Cardinal Corp., 601 W. Eichel Ave., Evansville 7, Ind.
Kentucky Metal Products Co., Preston St. & Audubon Park, Louisville 4, Ky.
Polar Hardware Co., 1631 S. Michigan Ave., Chicago 16, Ill.
Sneath Glass Co., Hartford City, Ind.
E. H. Titchener & Co., Binghamton, N.J.

Union Steel Products Co., 448 Pine St., Albion, Mich. *(p. 182)*
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
United Steel & Wire Co., Battle Creek, Mich.
Wall Wire Products Co., 11333 General Dr., Plymouth, Mich.
L. A. Young Spring & Wire Corp., 9200 Russell St., Detroit 11, Mich.

SHIELDS, EXPANSION (See also ANCHORS)

Chicago Expansion Bolt Co., 1338 W. Concord Place, Chicago 22, Ill.
Star Expansion Bolt Co., 147 Cedar St., N.Y.C. 6
U. S. Expansion Bolt Co., York, Pa.

SHIMS

Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Laminated Shim Co., Inc., Union St., Glenbrook, Ct.
National Motor Bearing Co., Inc., Redwood City, Cal.
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.

SHOCK ABSORBERS (See VIBRATION ABSORBING BASES)

SHUTTERS, AUTOMATIC (See also LOUVRES)

Allen Ventilating Div., Production Planning Co., 704 Woodward, Rochester, Mich.
Arex Co., 333 N. Michigan Ave., Chicago 1, Ill.
Bishop & Babcock Mfg. Co., 4901 Hamilton Ave., N.E., Cleveland 14, O.
Johnson Fan & Blower Corp., 1318 W. Lake St., Chicago 7, Ill.
H. H. Robertson Co., 2400 Farmers' Bank Bldg., Pittsburgh 22, Pa.
V. E. Sprouse Co., Inc., Columbus, Ind.
L. J. Wing Mfg. Co., 154 W. 14th St., N.Y.C. 11

SIGHT GLASSES (See LIQUID INDICATORS)

SIGNALS, ELECTRIC (See also ALARMS)

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Enterprise Products Co., P.O. Box 577, Freeport, Ill.
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
Tork Clock Co., Inc., 1 Grove St., Mt. Vernon, N.Y.

SIGNS (See also NAME PLATES)

Acromark Co., 5 Morrell St., Elizabeth 5, N.J.
Artkraft Mfg. Corp., Kibby St. & D.T.&I. R.R., Lima, O.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Mine Safety Appliances Co., Braddock, Thomas & Meade Sts., Pittsburgh, Pa.
Amos Thompson Corp., Edinburg, Ind.

SILICA GEL (See DEHYDRANTS)

SILVER

Handy & Harman, 82 Fulton St., N.Y.C. 7
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.

SLEEVES, CYLINDER

McQuay-Norris Mfg. Co., 2320 Marconi Ave., St. Louis 10, Mo.
Amos Thompson Corp., Edinburg, Ind.

SLIDES, DRAWER (See also BEARINGS, BALL, for DRAWERS)

Brasco Mfg. Co., Harvey, Ill.
Knape & Vogt Mfg. Co., Grand Rapids 4, Mich.
Standard-Keil Hardware Mfg. Co., Inc., 639 B'way, N.Y.C. 12

SODA FOUNTAINS, FOUNTAINETTES & EQUIPMENT (See also CARBONATORS, etc.)

Ace Cabinet Corp., 110 E. 42nd St., N.Y.C. 17
Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 4, Ill.
Horace A. Carter, Inc., 16 E. Marshall St., Richmond 19, Va.
Stanley Knight Corp., 3430 N. Pulaski Rd., Chicago 41, Ill.
Liquid Carbonic Corp., 3100 S. Kedzie Ave., Chicago 23, Ill.
Nelson Mfg. Co., 4016 N. Union St., St. Louis 15, Mo.
Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.

SODIUM CHLORIDE

Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Phila. 7, Pa.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.

SODIUM DICHROMATE (See WATER TREATING MATERIALS)

SOFTENERS, WATER (See WATER TREATING MATERIALS)

SOLDER (See also SOLDER, SILVER)

All-State Welding Alloys Co., Inc., 273 Ferris Ave., White Plains, N.Y.
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Lenk Mfg. Co., Newton Lower Falls 62, Mass.
National Lead Co., 111 Broadway, N.Y.C. 6
Northern Indiana Brass Co., 935 Plum St., Elkart, Ind.
Northwest Lead Co., 2700-16th Ave., S.W., Seattle 4, Wash.

SOLDER, SILVER

All-State Welding Alloys Co., Inc., 273 Ferris Ave., White Plains, N.Y.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
General Plate Div., Metals & Controls Corp., Attleboro, Mass.
Handy & Harman, 82 Fulton St., N.Y.C. 7
Chas W. Krieg Co., 48 Dickerson St., Newark 4, N.J.
Lucas Milhaupt Engrg. Co., 5051 S. Lake Drive, Milwaukee, Wis.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls. Ind.
National Lead Co., 111 Broadway, N.Y.C. 6
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

SOLENOID VALVES, REFRIGERANT
(A—Ammonia; B—Other refrigerants)

(A,B) Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
(B) Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
(A,B) Automatic Switch Co., 391 Lakeside Ave., Orange, N.J.
(B) Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
(A,B) Electrimatic Div. at Jas. P. Marsh Corp., 3501 Howard St., Skokie, Ill.
(A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
(A,B) General Controls Co., 801 Allen Ave., Glendale, Cal. *(p. 67)*
(B) Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
(A,B) Henry Valve Co., Melrose Park, Ill. *(p. 212)*
(A,B) Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
(B) Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
(A,B) Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
(A,B) Sporlan Valve Co., 7525 Sussex Ave., St. Louis 17, Mo.

SOLENOID VALVES, WATER, BRINE, etc.

Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
Automatic Switch Co., 391 Lakeside Ave., Orange, N.J.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
Electrimatic Div. at Jas. P. Marsh Corp., 3501 Howard St., Skokie, Ill.
Erickson Specialty Co., 10 Cayuga St., Cohoes, N.Y.
Hays Mfg. Co., 21st & Liberty Sts., Erie, Pa.
Henry Valve Co., Melrose Park, Ill. *(p. 212)*
Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Supreme Elec. Products Co., 194 Vassar St., Rochester 7, N.Y.

SPEED INDICATORS (See TACHOMETERS)

SPEED CHANGERS; also VARIABLE SPEED TRANSMISSIONS

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Charles Bond Co., 617-23 Arch St., Phila., Pa.
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
Fafnir Bearing Co., 37 Booth St., New Britain, Ct.
Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Janette Mfg. Co., 556 W. Monroe St., Chicago 6, Ill.
W. A. Jones Foundry & Machine Co., 4401 Roosevelt Rd., Chicago 24, Ill.
Link-Belt Co., 2045 W. Hunting Park, Phila. 40, Pa.
Philadelphia Gear Wks., Inc., G St. & Erie Ave., Phila. 20, Pa.
Reliance Elec. & Engrg. Co., 1088 Ivanhoe Rd., Cleveland 10, O.
Star Elec. Motors Co., 200 Bloomfield Ave., Bloomfield, N.J.
Stephens-Adamson Mfg. Co., Ridgeway Ave., Aurora, Ill.
Twin Disc Clutch Co., Racine, Wis.
Westinghouse Elec. Corp., 200 McCandless Ave., Pittsburgh 1, Pa.

SPEED NUTS & CLIPS (See FASTENERS)

SPONGE RUBBER PARTS (See RUBBER PRODUCTS, CELLULAR)

SPRAY ELIMINATORS

Farr Co., 2615 Southwest Dr., Los Angeles 43, Cal.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Harry Cooling Towers, Inc., West St., Doylestown, Pa. *(p. 74)*

SPRAY HUMIDIFIERS (See also HUMIDIFIERS)

Binks Mfg. Co., 3114 Carroll Ave., Chicago 16, Ill.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill
Marley Co., Inc., 3001 Fairfax Rd., Kansas City 15, Kan. *(p. 75)*
D. J. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Parks-Cramer Co., Box 444, Fitchburg, Mass.
Spraying Systems Co., 3201 Randolph St., Bellwood, Chicago, Ill.
Walton Laboratories, Inc., 1186 Grove St., Irvington 11, N.J.

SPRAY NOZZLES (See NOZZLES)

SPRAY PONDS (See COOLING PONDS)

SPRAY TYPE EVAPORATORS (See UNIT COOLERS)

SPRINGS

American Spring & Wire Specialty Co., 816 N. Spaulding Ave., Chicago 51, Ill.
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Hunter Pressed Steel Co., 801 Maple St., Lansdale, Pa.
L. A. Young Spring & Wire Corp., 9200 Russell St., Detroit 11, Mich.

SPROCKETS

Charles Bond Co., 617-23 Arch St., Phila., Pa.
Cyclone Fence Div., American Steel & Wire Co., U. S. Steel Corp. Subsidiary, P.O. Box 260, Waukegan 1, Ill.
Diamond Chain Co., Inc., 402 Kentucky Ave., Indpls. 7, Ind.
Link-Belt Co., 519 Holmes Ave., Indpls. 6, Ind.
Morse Chain Co., Div. of Borg-Warner Corp., Ithaca, N.Y.

STAMPINGS (See also SHAPES)

Ackermann Mfg. Co., Wheeling, W. Va.
Acklin Stamping Co., 1929 Nebraska Ave., Toledo 7, O. *(p. 185)*
Alloy Products Corp., 1045 Perkins Ave., Waukesha, Wis.
Aluminum Goods Mfg. Co., Manitowoc, Wis.
American Brass Co., Waterbury 88, Ct. *(p. 199)*
American Central Mfg. Corp., Div. of Avco Corp., 18th & Columbia Sts., Connersville, Ind.
American Emblem Co., Inc., P.O. Box 116-H. Utica 1, N.Y.
Atlantic Steel Co., P.O. Box 1714, Atlanta, 1, Ga.
Behringer Metal Wks., Inc., 108 Jabez St., Newark 5, N.J.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Bingham Herbrand Co., 1062 S. Post St., Toledo 6, O.
Bossert Co., P.O. Drawer 358, Utica 1, N.Y.
A. S. Campbell & Co., Inc., E. Boston 28, Mass.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Columbia Metal Stamping Co., 1900 Harvard Ave., Cleveland, O.
Commercial Shearing & Stamping Co., 1775 Logan St., Youngstown, O.
Crandal-Stone Div., Brewer-Titchener Corp., 336 Court St., Binghamton, N.Y.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
Erie Art Metal Co., 1602 E. 18 St., Erie, Pa.
Fox Co., Fox Lane, Cin'ti. 23, O.
Gillian Mfg. Co., 7750 Dubois Ave., Detroit 11, Mich.
Globe Stamping Div., Hupp Corp., 1250 W. 76th St., Cleveland 2, O.
L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Greene Mfg. Co., 1028 Douglas Ave., Racine, Wis.
Heintz Mfg. Co., Front St. & Olney Ave., Phila. 20, Pa.
Hoosier Cardinal Corp., 601 W. Eichel Ave., Evansville 7, Ind.
Houdaille-Hershey Corp., 1900 Foss Park Ave., N. Chicago, Ill. *(p. 165)*
Hugo Mfg. Co., 49 Ave. W. & Superior St., Duluth 7, Minn.
Hunter Pressed Steel Co., 801 Maple St., Lansdale, Pa.
Lansing Stamping Co., 1159 S. Pennsylvania Ave., Lansing 2, Mich.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
Melrath Supply & Gasket Co., Inc., Tioga & Memphis Sts., Phila. 34, Pa.
Metal Specialty Co., Este Ave. & B&O R.R., Cin'ti., O.
Minerallac Elec. Co., 25 N. Peoria St., Chicago 7, Ill.
Mullins Mfg. Corp., S. Ellsworth St., Salem, O.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Northern Engraving & Mfg. Co., 4th & Vine Sts., La Crosse, Wis.
Paine Co., 2951 Carroll Ave., Chicago 12, Ill.
Powell Pressed Steel Co., Hubbard, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 19[illegible])*
Robinson Aviation, Inc., Teterboro N.J.
Shakeproof, Inc., 2501 N. Keeler Ave., Chicago 39, Ill.
Stanley Wks., 195 Lake St., New Britain, Ct.

iperior Spinning & Stamping Co., 4057 Fitch Rd., Toledo 12, O.
vift Mfg. Co., Inc., 1455 E. Nine Mile Rd., Hazel Park, Mich.
oledo Stamping & Mfg. Co., 99 Fearing Blvd., Toledo 7, O.
ransue & Williams Steel Forging Corp., Alliance, O.
. R. Wagner Mfg. Co., 4001 N. 32nd St., Milwaukee, Wis.
'all Wire Products Co., 11333 General Dr., Plymouth, Mich.
'heeling Steel Corp., Wheeling, W. Va.
'hitehead Stamping Co., 1661 W. Lafayette Blvd., Detroit 16, Mich.
'orcester Pressed Steel Co., 100 Barber Ave., Worcester 6, Mass.
'rought Washer Mfg. Co., 2253 S. Bay St., Milwaukee 7, Wis.

TANDARDS. SHELF (See SUPPORTS)

TAPLES

astener Corp., 860 Fletcher St., Chicago 14, Ill.
eller Co., 2135 Superior Ave., N.E., Cleveland 4, O.

TARTERS, MOTOR

llen-Bradley Co., Milwaukee 4, Wis.
llis-Chalmers Mfg. Co., Milwaukee 1, Wis.
rrow-Hart & Hegman Elec. Co., 103 Hawthorn St., Hartford 6, Ct. (Manual)
org-Erickson Corp., 469 E. Ohio St., Chicago 11, Ill.
'lark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
'utler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
'lectric Controller & Mfg. Co., 2700 E. 79th St., Cleveland 4, O.
Electric Machinery Mfg. Co., 1338 Tyler St., N.E., Minneapolis 13, Minn.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Paragon Elec. Co., 1600-12th St., Two Rivers, Wis.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Spencer Thermostat Div., Metals & Controls Corp., 34 Forest St., Attleboro, Mass.
Square D Co., Inc., 6060 Rivard St., Detroit 11, Mich.
Trumbull Elec. Mfg. Co., 999 Woodford Ave., Plainville, Ct.
Westinghouse Elec. Corp., Beaver, Pa.

STEAM COILS (See AIR CONDITIONING COILS)

STEAM JET VACUUM COOLING SYSTEMS (See also EJECTORS)

Croll-Reynolds Engrg. Co., Inc., 17 John St., N.Y.C.
Elliott Co., Jeanette, Pa.
Foster Wheeler Corp., 165 Broadway, N.Y.C.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Ross Heater & Mfg. Co., Div. of American Radiator & Standard Sanitary Corp., Buffalo 13, N.Y.
Schutte & Koerting Co., 12th & Thompson Sts., Phila. 22, Pa.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

STEAM SEPARATORS

American District Steam Co., Bryant St., N. Tonawanda, N.Y.
Cochrane Corp., 17th St., below Allegheny Ave., Phila. 32, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*

(Continued)

STEAM SEPARATORS (Continued)

Johnson Corp., 805 Wood St., Three Rivers, Mich.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
Wilson Engrg. Corp., 122 S. Michigan Ave., Chicago 3, Ill.
Wright-Austin Co., 315 W. Woodbridge St., Detroit 26, Mich.

STEAM TRAPS

American District Steam Co., Bryant St., N. Tonawanda, N.Y.
Armstrong Machine Wks., 831 Maple St., Three Rivers, Mich. *(p. 164)*
V. D. Anderson Co., 1935 W. 96th St., Cleveland 2, O.
Barnes & Jones, Inc., 128 Brookside Ave., Jamaica Plain 30, Mass.
Bishop & Babcock Mfg. Co., 4901 Hamilton Ave., N.E., Cleveland 14, O.
W. D. Cashin Co., 69 A St., S. Boston 27, Mass.
Climax Engrg. Co., Controls Div., 15 N. Cincinnati, Tulsa, Okla.
Cochrane Corp., 17th St., below Allegheny Ave., Phila. 32, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
C. A. Dunham Co., 400 W. Madison St., Chicago 6, Ill.
Hoffman Specialty Co., Inc., 1001 York St., Indpls., Ind.
O. C. Keckley Co., 400 W. Madison St., Chicago 6, Ill.
Marsh Heating Equip. Co., 3501 Howard St., Skokie, Ill.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Polar Hardware Co., 1631 S. Michigan Ave., Chicago 16, Ill.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Sterling, Inc., 3738 N. Holton St., Milwaukee 12, Wis.
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
Trane Co., La Crosse, Wis. *(p. 12)*
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
Warren Webster & Co., Camden, N.J.
Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburgh 12, Pa.
Wright-Austin Co., 315 W. Woodbridge St., Detroit 26, Mich.
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.

STEAM TURBINES

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Dean Hill Pump Co., 4000 E. 16th St., Indpls. 7, Ind.
DeLaval Steam Turbine Co., 853 Nottingham Way, Trenton 2, N.J.
Elliott Co., Jeannette, Pa.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Dean Hill Pump Co., 4000 E. 16th St., Indpls. 7, Ind.
Terry Steam Turbine Co., Hartford 1, Ct.
Westinghouse Elec. Corp., S. Phila. 1, Pa.
L. J. Wing Mfg. Co., 154 W. 14th St., N.Y.C. 11
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

STEEL (See particular mill forms, i.e., BAR, SHEET, etc.)

STEEL, COMPRESSOR VALVE

Athenia Steel Div., National-Standard Co., Clifton, N.J.
Bethlehem Steel Co., Bethlehem, Pa.
Sandvik Steel, Inc., 111-8th Ave., N.Y.C. 11 (Swedish Steel)

STEEL PLATE FABRICATION

Behringer Metal Wks., Inc., 108 Jabez St., Newark 5, N.J.
Bethlehem Steel Co., Bethlehem, Pa.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
Central Iron & Steel Co., Harrisburg, Pa.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago 1, Ind.
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey City 7, N.J.
McNamara & Co., Inc., 2700 Manokin St., Baltimore 30, Md.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Wright-Austin Co., 315 W. Woodbridge St., Detroit 26, Mich.

STEEL, STRUCTURAL (See SHAPES, STRUCTURAL)

STERILIZERS, AIR (See AIR PURIFICATION EQUIPMENT)

STILLS, AMMONIA

Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh, Pa.

STRAINERS, AIR

Alco Valve Co., 855 Kingsland Ave.,, St. Louis 5, Mo. *(p. 95)*
American Flexible Coupling Co., 1808 Pittsburgh Ave., Erie, Pa.
A. W. Cash Co., 540 N. 18th St., Decatur, Ill.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Cryer Trap & Valve Co., 366 Madison Ave., N.Y.C.
Davis Regulator Co., 2511 S. Washtenaw Ave., Chicago 8, Ill.
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
O. C. Keckley Co., 400 W. Madison St., Chicago 6, Ill.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
C. A. Norgren, 222 Santa Fe Drive, Denver, Col.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Sterling, Inc., 3738 N. Holton St., Milwaukee 12, Wis.
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
Water Cooling Corp., 71 Nassau St., N.Y.C. 7

STRAINERS, OIL

Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
American Flexible Coupling Co., 1808 Pittsburgh Ave., Erie, Pa.
Anthony Co., 47-33-5th St., Long Island City, N.Y.
Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Ill.
A. W. Cash Co., 540 N. 18th St., Decatur, Ill.
W. D. Cashin Co., 69 A St., S. Boston 27, Mass.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Cuno Engrg. Corp., 92 S. Vine St., Meriden, Ct.
Davis Regulator Co., 2511 S. Washtenaw Ave., Chicago 8, Ill.
Delavan Mfg. Co., 3009-6th Ave., Des Moines 13, Ia.
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Fischer & Porter Co., Hatboro, Pa.
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
McIntire Connector Co., 252 Jefferson St., Newark 5, N.J. *(p. 84)*
Michigan Wire Cloth Co., 2098 Howard St., Detroit 16, Mich.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Schutte & Koerting Co., 12th & Thompson Sts., Phila. 22, Pa.
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
J. A. Zurn Mfg. Co., Erie, Pa.

STRAINERS, REFRIGERANT

Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
American Flexible Coupling Co., 1808 Pittsburgh Ave., Erie, Pa.
Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*
Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
A. W. Cash Co., 540 N. 18th St., Decatur, Ill.
Cuno Engrg. Corp., 92 S. Vine St., Meriden, Ct.
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Electromatic Div. at Jas. P. Marsh Corp., 3501 Howard St., Skokie, Ill.
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Henry Valve Co., Melrose Park, Ill. *(p. 187)*
Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Industrial Wire Cloth Products Corp., Wayne, Mich. *(p. 85)*
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
McIntire Connector Co., 252 Jefferson St., Newark 5, N.J. *(p. 84)*
Madden Brass Products Co., 1111 N. Franklin St., Chicago 10, Ill.
Michigan Wire Cloth Co., 2098 Howard St., Detroit 16, Mich.
Moraine Products Div., Gen'l. Motors Corp., Dayton 1, O.
Mueller Brass Co., Port Huron, Mich.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
Remco, Inc., Zelienople, Pa. *(p. 107)*
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Wabash Mfg. Co., 2300 South Western Ave., Chicago 8, Ill.
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

STRAINERS, STEAM, WATER, etc.

Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
American District Steam Co., Bryant St., N. Tonawanda, N.Y.
American Flexible Coupling Co., 1808 Pittsburgh Ave., Erie, Pa.
A. W. Cash Co., 540 N. 18th St., Decatur, Ill.
James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Cochrane Corp., 17th St., below Allegheny Ave., Phila. 32, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Cuno Engrg. Corp., 92 S. Vine St., Meriden, Ct.
Davis Regulator Co., 2511 S. Washtenaw Ave., Chicago 8, Ill.
Delavan Mfg. Co., 3009-6th Ave., Des Moines 13, Ia.
Dollinger Corp., 1 Centre Park, Rochester 3, N.Y.
Electromatic Div. at Jas. P. Marsh Corp., 3501 Howard St., Skokie, Ill.
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Fischer & Porter Co., Hatboro, Pa.
General Controls Co., 801 Allen Ave., Glendale, Cal. *(p. 67)*
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Henry Valve Co., Melrose Park, Ill. *(p. 187)*
Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
O. C. Keckley Co., 400 W. Madison St., Chicago 6, Ill.
Leslie Co., Valley Brook & Grant Ave., Lyndhurst, N.J.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
Marsh Heating Equip Co., 3501 Howard St., Skokie, Ill.
Jos. A. Martocello & Co., 229 N. 14th St., Phila. 7, Pa. *(p. 147)*
Monarch Mfg. Wks., Inc., Salmon & Westmorland Sts., Phila. 34, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
Neptune Meter Co., 50. W. 50th St., N.Y.C. 20
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Schutte & Koerting Co., 12th & Thompson Sts., Phila. 22, Pa.
Spray Engrg. Co., 114 Central St., Somerville 45, Mass.
Spraying Systems Co., 4021 W. Lake St., Chicago 24, Ill
Sterling, Inc., 3738 N. Holton St., Milwaukee 12, Wis.
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
Supreme Elec. Products Co., 194 Vassar St., Rochester 7, N.Y.
Trane Co., La Crosse, Wis. *(p. 12)*
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Water Cooling Corp., 71 Nassau St., N.Y.C. 7
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.
Wright-Austin Co., 315 W. Woodbridge St., Detroit 26, Mich.
Yarnall-Waring Co., Chestnut Hill, Phila. 18, Pa.
J. A. Zurn Mfg. Co., Erie, Pa.

STRAINERS, WELL

A. D. Cook, Inc., Lawrenceburg, Ind.

STRAPS, TUBE (See CLAMPS)

STRIP, ALUMINUM

Aluminum Co. of America, Pittsburgh 19, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Fairmont Aluminum Co., Fairmont, W. Va.
Permanente Products Co., 1924 Broadway, Oakland 12, Cal.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.

STRIP, BERYLLIUM COPPER

Athenia Steel Div., National Standard Co., Clifton, N.J.
Beryllium Corp., P.O. Box 1462, Reading, Pa.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.

STRIP, BRASS, BRONZE, COPPER

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Bristol Brass Corp., Bristol, Ct.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
C. G. Hussey & Co., 2860-2nd Ave., Pittsburgh 19, Pa.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind. (Alloy)
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Western Brass Mills, Div. of Olin Industries, Inc., E. Alton, Ill.

STRIP, INCONEL, MONEL, NICKEL

Central Steel & Wire Co., 3000 W. 51st St., Chicago 32. Ill.
Driver-Harris Co., Harrison, N.J.
International Nickel Co., 67 Wall St., N.Y.C. 5
Superior Steel Corp., Carnegie, Pa. (Monel & Nickel Clad)

STRIP, STEEL

Acme Steel Co., 2840 Archer Ave., Chicago 8, Ill.
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Armco Steel Corp., Middletown, O.
Athenia Steel Div., National-Standard Co., Clifton, N.J
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Bethlehem Steel Co., Bethlehem, Pa.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp Subsidiary, Brown-Marx Bldg., Birmingham, Ala.
Weirton Steel Co., Weirton W. Va.
Wheeling Steel Corp., Wheeling, W. Va.

STRIP, STEEL, COATED, CLAD or GALVANIZED

Acme Steel Co., 2840 Archer Ave., Chicago 8, Ill.
Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Armco Steel Corp., Middletown, O.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
National Lead Co., 111 Broadway, N.Y.C. 6
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Superior Steel Corp., Carnegie, Pa.
Weirton Steel Co., Weirton, W. Va.
Wheeling Steel Corp., Wheeling, W. Va.

STRIP, STEEL, STAINLESS

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Armco Steel Corp., Middletown, O.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Carpenter Steel Co., Reading, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Driver-Harris Co., Harrison, N.J.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Rigidized Metals Corp., 658 Ohio St., Buffalo 3, N.Y.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Superior Steel Corp., Carnegie, Pa.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.

STRIP, ZINC

New Jersey Zinc Co., 160 Front St., N.Y.C. 7

STRIP HEATERS (See HEATER ELEMENTS)

STRUCTURAL SHAPES (See SHAPES, STRUCTURAL)

STRUCTURAL STEEL FABRICATION

Behringer Metal Wks., Inc., 108 Jabez St., Newark 5, N.J.
Bethlehem Steel Co., Bethlehem, Pa.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
California Steel Products Co., Barrett & "A" Sts., Richmond, Cal.
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey City 7, N.Y.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
McNamara & Co., Inc., 2700 Manokin St., Baltimore 30, Md.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.

STRUCTURE, PREFABRICATED

California Steel Products Co., Barrett & "A" Sts., Richmond, Cal.
Lindsay Structure, Inc. 1740-25th Ave., Melrose Park, Ill.

STUDS (See BOLTS, MACHINE & STUD)

SUCTION PRESSURE REGULATING VALVES (See also TWO TEMPERATURE VALVES)

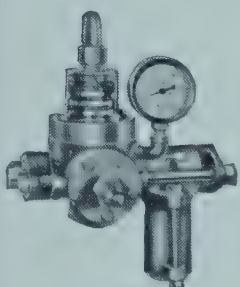
Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*
Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
A. W. Cash Co., 540 N. 18th St., Decatur, Ill.

(Continued)

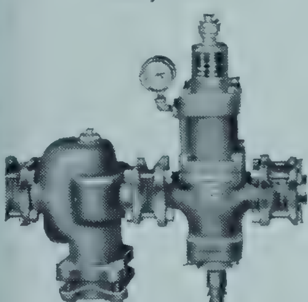
Hubbell Corporation

P.O. Box 700, Hawley Rd.
Mundelein, Ill.

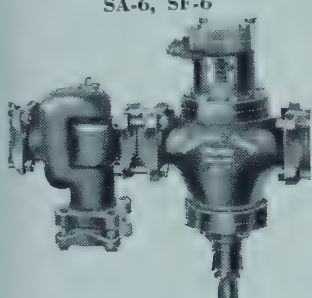
Designers and Manufacturers of Automatic Control Valves For All Refrigerants



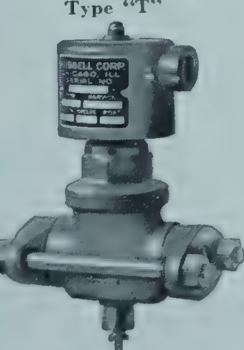
TYPE
SA-5, SF-5



TYPE
SA-6, SF-6



Type "T"



TYPE
A-2

Type SA-5, SA-6, SF-5 and SF-6 Back Pressure Regulating Valves are of the conventional type used to maintain a constant evaporator pressure.

Type SA-7, SA-8, SF-7 and SF-8 Combination Back Pressure Regulator and Stop Valves. This regulator is of the conventional type used to maintain a constant evaporator pressure and the addition of a small electric pilot valve built into the head, makes it a suction stop valve.

The DSA-9 and DSF-9 is a dual regulator which will control evaporators with two load conditions requiring different refrigerant temperatures. The diaphragms in the dual head may be set for any two evaporator pressures and will automatically change from one to the other by the opening or closing of the electric pilot valve which is built into the head.

The SAC-6 and SFC-6 valves are of the compensating type and are used where a constant temperature is desired in the medium being cooled. These valves will increase or decrease the evaporator pressure to compensate for the increase or decrease of the cooling load. These valves are made to operate with air or electricity.

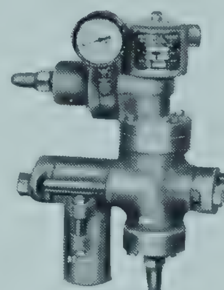
The Type "T" suction stop valve is used on installations where automatic suction line control is required. It is operated by high pressure gas and its construction makes a tight closing valve and its dependability far surpasses the conventional magnetic stop valve.

All of the valves have built-in opening stems, which eliminates the by-passes usually used for manual operation. Available with either screwed, welding type flanges or copper tube connections, in sizes from ¾" to 8" inclusive.

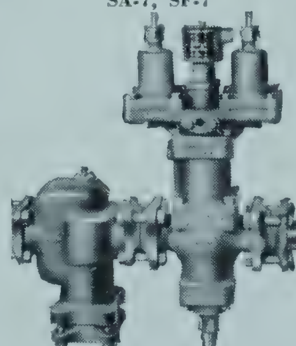
Solenoid Valves from ⅜" to 2" inclusive for liquids and gases with composition seat discs readily renewable, coils for any electrical characteristics, built-in lifting stem standard, available with either screwed, welding flanges or copper tube connections.

Strainers are available in all sizes for liquid and gas with very large screen areas and arranged to bolt directly to valve or with screwed, welding flange or copper tube connections for installation wherever strainer is necessary.

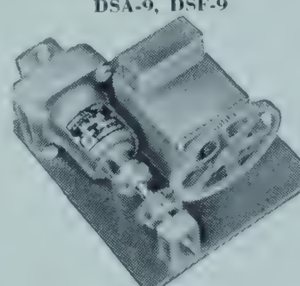
Write for complete information on these and our many additional Refrigeration Controls and Accessories.



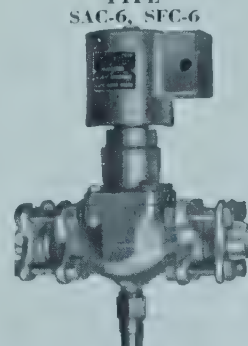
TYPE
SA-7, SF-7



TYPE
DSA-9, DSF-9



TYPE
SAC-6, SFC-6



TYPE
A-3, F-4

SUCTION PRESSURE REGULATING VALVES (Continued)

Climax Engrg. Co., Controls Div., 15 N. Cincinnati, Tulsa Okla.
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Electrimatic Div. at Jas. P. Marsh Corp., 3501 Howard St., Skokie, Ill.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Hays Corp., Michigan City, Ind.
Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
Madden Brass Products Co., 1111 N. Franklin St., Chicago 10, Ill.
Mason-Neilan Regulator Co., 1190 Adams St., Boston 24, Mass.
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p. 86)*

SULFUR DIOXIDE

Ansul Chemical Co., Marinette, Wis. *(p. 167)*
Eston Chemicals, Inc., 3100 E. 26th St., Los Angeles 23, Cal.
Great Western Div., Dow Chemical Co., 310 Sansome St., San Francisco 4, Cal.
Virginia Smelting Co., W. Norfolk, Va. *(p. 168)*

SUPPORTS, SHELF (See also HOOKS; also HARDWARE SPECIALTIES)

Brasco Mfg. Co., Harvey, Ill.
General Industries Co., Olive & Taylor Sts., Elyria, O.
Knape & Vogt Mfg. Co., Grand Rapids 4, Mich.
Lexington Supply Co., 4815 Lexington Ave., Cleveland 3, O.
National Lock Co., 7th St. & 18th Ave., Rockford, Ill. *(p. 121)*
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Standard-Keil Hardware Mfg. Co., 639 Broadway, N.Y.C. 12
Standard Products Co., 505 Blvd. Bldg., Detroit 2, Mich.
Amos Thompson Corp., Edinburg, Ind.
Wall Wire Products Co., 11333 General Dr., Plymouth, Mich.

SUPPORTS, TUBE (See CLAMPS)

SURGE TANKS (See ACCUMULATORS)

SWING JOINTS

Barco Mfg. Co., 1801 Winnemac Ave., Chicago 40, Ill.
L. J. Bordo Co., Inc., 115 New St., Glenside, Pa.
Chicago Screw Co., 2701 Washington Blvd., Bellwood, Ill.
Dresser Mfg. Div., Dresser Industries. Inc., 490 Fisher Ave., Bradford, Pa.
Flexo Supply Co., Inc., 4649 Page Blvd., St. Louis 13, Mo.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Water Cooling Corp., 71 Nassau St., N.Y.C. 7

SWITCHES, ELECTRIC (See also FLOAT SWITCHES; also STARTERS, MOTOR; also TIME SWITCHES)

Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
Allen Bradley Co., Milwaukee 4, Wis.
Arrow-Hart & Hegeman Elec. Co., 103 Hawthorn St., Hartford 6, Ct.
Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Automatic Switch Co., 391 Lakeside Ave., Orange, N.J.
Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Bryant Elec. Co., Div. of Westinghouse Elec. Corp., 1421 State St., Bridgeport 2, Ct.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Clarostat Mfg. Co., Inc., 130 Clinton St., Brooklyn 2, N.Y

ook Elec. Co., 2700 Southport Ave., Chicago 14, Ill.
utler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
ura Kool, Inc., 1010 N. Main St., Elkhart, Ind.
eneral Elec. Co., 1285 Boston Ave., Bridgport 2, Ct.
eneral Elec. Co., 1 River Rd., Schenectady 5, N.Y.
lart Mfg. Co., 110 Bartholomew Ave., Hartford 1, Ct.
IcDonnell & Miller, Inc., 1316 Wrigley Bldg., Chicago 11, Ill.
IcGill Mfg. Co., Inc., Valparaiso, Ind.
Iagnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
V. L. Maxson Corp., 460 W. 34th St., N.Y.C. 1
Iercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Iicro Switch Div., First Industrial Corp., Freeport, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Iu-Switch Div., Chase-Shawmut Co., 38 Pequit St., Canton, Mass.
hmite Mfg. Co., 4835 W. Fluornoy St., Chicago 44, Ill.
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
ent Elec. Co., Inc., 634 Michigan Trust Bldg., Grand Rapids 2, Mich.
Ranco, Inc., 601 W. 5th Ave., Columbus 1, O. *(p. 69)*
Soreng Mfg. Corp, 9555 Eden Ave., Schiller Park, Ill.
Spencer Thermostat Div., Metals & Controls Corp., 34 Forest St., Attleboro, Mass.
Trumbull Elec. Mfg. Co., 999 Woodford Ave., Plainville, Ct.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Westinghouse Elec. Corp., Beaver, Pa.
Western Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

SWITCHGEAR

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Automatic Switch Co., 391 Lakeside Ave., Orange, N.J.
Electric Machinery Mfg. Co., 1338 Tyler St., N.E., Minneapolis 13, Minn.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
I-T-E Circuit Breaker Co., 19th & Hamilton Sts., Phila. 30, Pa.
Trumbull Elec. Mfg. Co., 999 Woodford Ave., Plainville, Ct.
Westinghouse Elec. Corp., E. Pittsburgh, Pa.

SWIVEL JOINTS (See SWING JOINTS)

SYNTHETIC RUBBER (See RUBBER PRODUCTS)

TACHOMETERS

Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct. (Recording, Elec.)
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Corbin Screw Corp., New Britain, Ct.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Reliance Elec & Engrg. Co, 1088 Ivanhoe Rd., Cleveland 10, O.
Veeder-Root, Inc., Garden & Sargeant Sts., Hartford 2, Ct. (Laboratory only)
Westinghouse Elec. Corp., Plane & Orange Sts., Newark 1, N.J.
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

TAGS (See NAME PLATES)

TANKS

Arrow Tank Co., Inc., 16 Barnett St., Buffalo 15, N.Y. (Wood)
Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Bethlehem Steel Co., Bethlehem, Pa.
Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
Bossert Co., P.O. Drawer 358, Utica 1, N.Y.
Central Iron & Steel Co., Harrisburg, Pa.
Cleveland Coppersmithing Wks., 5500 Stone Ave., Cleveland 2, O.
Concrete Forms Corp., 43 Cedar St., N.Y.C. 3
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
Falstrom Co., 13 Falstrom Court, Passaic, N.J.
Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
Frick Co., Waynesboro, Pa. *(p. 44)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Graver Tank & Mfg. Co., Inc., 4809 Tod Ave., E. Chicago 1, Ind.
Joseph Kopperman & Sons, 312 New St., Phila. 6, Pa.
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey City 7, N.J.
McNamara & Co., Inc., 2700 Manokin St., Baltimore 30, Md.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
National Carbon Co., Inc., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55)*
Pittsburgh-Des Moines Construction Co., Neville Island, Pittsburgh 25, Pa.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Edw. W. Renneburg & Sons Co., 2639 Boston Ave., Baltimore 24, Md.
Emil Steinhorst & Sons, Inc., 612 South St., Utica 3, N.Y.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber)
Wildman Boiler & Tank Co., 3026 Carroll Ave., Chicago 12, Ill.
York Corp., York, Pa. *(p. 119)*

TANKS, HOT WATER

Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Biggs Boiler Wks. Co., 1000 Bank, Akron 5, O.
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey City, 7, N.J.
R. Munroe & Sons Mfg. Corp., 23rd & Smallman Sts., Pittsburgh 22, Pa.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55)*
Rheem Mfg. Co., 570 Lexington Ave., N.Y.C. 22
Stover Steel Tank & Mfg. Co., 100 S. Hancock St., Freeport, Ill.
Wheeling Steel Corp., Wheeling, W. Va.
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.

TANKS, MILK HOLDING

Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
Concrete Forms Corp., 43 Cedar St., N.Y.C. 3
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Gustav Glaser Co., Inc., 2 Wait St., Paterson 4, N.J.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Emil Steinhorst & Sons, Inc., 612 South St., Utica 3, N.Y.

TANKS, PRESSURE (See PRESSURE VESSELS)

TANK HEADS

Ackermann Mfg. Co., Wheeling, W. Va.
Bethlehem Steel Co., Bethlehem, Pa.
Central Iron & Steel Co., Harrisburg, Pa.
Commercial Shearing & Stamping Co., 1775 Logan St., Youngstown, O.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey City, 7, N.J.
Lukens Steel Co., Coatesville, Pa.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Wheeling Steel Corp., Wheeling, W. Va.

TAPE, FRICTION (See FRICTION TAPE)

TAPE, RUBBER

Boston Woven Hose & Rubber Co., P.O. Box 1071, Boston 3, Mass.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
New York Belting & Packing Co., 1 Market St., Passaic, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Van Cleef Bros., Inc., 7800 S. Woodlawn Ave., Chicago 19, Ill.

TEES, WELDING (See FITTINGS, PIPE)

TERMINALS & TERMINAL BLOCKS

Burke Elec. Co., Erie, Pa.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Shakeproof, Inc., 2501 N. Keeler Ave., Chicago 39, Ill.
Thompson-Bremer & Co., 1640 W. Hubbard St., Chicago 22, Ill.
United Mfg. & Service Co., 405 S. 6th, Milwaukee, Wis.

TERMINALS, HERMETIC

Fusite Corp., Carthage at Hannaford, Norwood, Cin'ti. 12, O.

TEST CABINETS (See REFRIGERATORS, LOW TEMPERATURE)

TESTING & RATING

U. S. Testing Co., Inc., 1415 Park Ave., Hoboken, N.J. *(p. 156)*

THERMOMETERS, ALARM

American Schaeffer & Budenberg Instrument Co., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Carroll Glass Instrument Co., 6742 Lebanon Ave., Phila. 31, Pa.
Electric Auto-Lite Co., Instrument & Gauge Div., Toledo 1, O.
Enterprise Products Co., P.O. Box 577, Freeport, Ill.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Manning, Maxwell & Moore, Inc., Stratford, Ct.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12

THERMOMETERS, CONTROLLING (See CONTROLLERS, TEMPERATURE)

THERMOMETERS, DAIRY

American Schaeffer & Budenberg Instrument Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Carroll Glass Instrument Co., 6742 Lebanon Ave., Phila. 31, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
GM Mfg. Co., 50 W. 3rd St., N.Y.C. 12
Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
Manning, Maxwell & Moore, Inc., Stratford, Ct.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti. 12, O.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
C. J. Tagliabue Mfg. Co., 550 Park Ave., Brooklyn 5, N.Y.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16 Mich.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

THERMOMETERS, DIAL

AC Spark Plug Div., Gen'l. Motors Corp., Flint 2, Mich.
American Schaeffer & Budenberg Instrument Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Anderson & Sons, Inc., N. Elm St., Westfield, Mass.
Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh 8, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Electric Auto-Lite Co., Instrument & Gauge Div., Toledo 1, O.
Fee & Stemwedel, Inc., 2210 Wabansia Ave., Chicago 47, Ill.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Hays Corp., Michigan City, Ind.
Johnson Service Co., 507 E. Michigan St., Milwaukee 22, Wis.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City, 16, Mo.
Liquidometer Corp., 41-03-36th St., Long Island City 1, N.Y.
Manning, Maxwell & Moore, Inc., Stratford, Ct.
Marshalltown Mfg. Co., Marshalltown, Ia.
Marsh Instrument Co., 3501 Howard St., Skokie, Ill.
James P. Marsh Corp., Skokie, Ill.
Moeller Instrument Co., Inc., 132nd St. & 89th Ave., Richmond Hill 18, N.Y.
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti 12, O.
Partlow Corp., 2 Campion Rd., New Hartford, N.Y.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Pyrometer Instrument Co., 103 Lafayette St., N.Y.C. 13
Rochester Mfg. Co., Inc., 100 Rockwood St., Rochester 10, N.Y.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Standard Thermometer, Inc., 952 Dorchester Ave., Boston 25, Mass.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C 12
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

THERMOMETERS, DUCT

Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44. Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
Dickson Co., 7420 Woodlawn Ave., Chicago 19, Ill.
Johnson Service Co., 507 E. Michigan St., Milwaukee 22, Wis.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*

Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti. 12, O.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

THERMOMETERS, HOUSEHOLD REFRIGERATOR

Carroll Glass Instrument Co., 6742 Lebanon Ave., Phila. 31, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Fee & Stemwedel, Inc., 2210 Wabansia Ave., Chicago 47, Ill.
GM Mfg. Co., 50 W. 3rd St., N.Y.V. 12
Marsh Instrument Co., 3501 Howard St., Skokie, Ill.
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Ohio Thermometer Co., 33 Walnut St., Springfield, O.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12

THERMOMETERS, INSERT

American Schaeffer & Budenberg Instrument Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Carroll Glass Instrument Co., 6742 Lebanon Ave., Phila. 31, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti. 12, O.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Pyrometer Instrument Co., 103 Lafayette St., N.Y.C. 13
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C 12

THERMOMETERS, MAXIMUM & MINIMUM REGISTERING

Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Friez Instrument Div., Bendix Aviation Corp., Taylor Ave. at Loch Raven Blvd., Towson, Baltimore 4, Md.
GM Mfg. Co., 50 W. 3rd St., N.Y.C. 12
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

THERMOMETERS, RECORDING

American Schaeffer & Budenberg Instrument Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Bacharach Industrial Instrument Co., 7000 Bennett St., Pittsburgh 8, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Defender Instrument & Regulator Co., 815 Clark Ave., St. Louis 2, Mo.
Electric Auto-Lite Co., Instrument & Gauge Div., Toledo 1, O.
Charles Engelhard, Inc., 850 Passaic Ave., E. Newark, N.J.
Ess Instrument Co., 96 S. Washington Ave., Bergenfield, N.J.
Foxboro Co., 38 Neponset Ave., Foxboro, Mass.
Friez Instrument Div., Bendix Aviation Corp., Taylor Ave. at Loch Raven Blvd., Towson, Baltimore 4, Md.
Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
Leeds & Northrup Co., 4970 Stenton Ave., Phila. 44, Pa.
Manning, Maxwell & Moore, Inc., Stratford, Ct.
Marsh Instrument Co., 3501 Howard St., Skokie, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Moore Products Co., H. & Lycoming Sts., Phila. 24, Pa.
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti. 12, O.
Partlow Corp., 2 Campion Rd., New Hartford, N.Y.
Standard Thermometer, Inc., 952 Dorchester Ave., Boston 25, Mass.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Thwing-Albert Instrument Co., Penn St. & Pulaski Ave., Phila. 44, Pa.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C 12

THERMOMETERS, WALL

Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
Fee Stemwedel, Inc., 2210 Wabansia Ave., Chicago 47, Ill.
GM Mfg. Co., 50 W. 3rd St., N.Y.C. 12
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
Marsh Instrument Co., 3501 Howard St., Skokie, Ill.
Nurnberg Thermometer Co., Inc., 134 Livingston St., Brooklyn 2, N.Y.
Palmer Thermometers, Inc., 2501 Norwood Ave., Cin'ti. 12, O.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Standard Thermometer, Inc., 952 Dorchester Ave., Boston 25, Mass.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. O. Trerice Co., 1420 W. Lafayette Blvd., Detroit 16, Mich.
U. S. Gauge, Div. of American Machine & Metals, Sellersville, Pa.
Weksler Thermometer Corp., 52 W. Houston St., N.Y.C. 12

THERMOREGULATORS

Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Carroll Glass Instrument Co., 6742 Lebanon Ave., Phila. 31, Pa.
Nurnberg Thermometer Co., Inc., 124 Livingston St., Brooklyn 2, N.Y.
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Weston Elec'l. Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N.J.

THERMOSTATIC BI-METALS

Baker & Co., Inc., 113 Astor St., Newark 5, N.J.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
W. M. Chace Co., 1601 Beard Ave., Detroit 9, Mich.
General Plate Div., Metals & Controls Corp., Attleboro, Mass.

THERMOSTATIC EXPANSION VALVES (See EXPANSION VALVES)

THERMOSTATS (See also CONTROLS, etc.)

Allen-Bradley Co., Milwaukee 4, Wis.
Barber-Colman Co., Rockford, Ill.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Detroit Lubricator Co., 5900 Trumbull Ave., Detroit 8, Mich.
Friez Instrument Div., Bendix Aviation Corp., Taylor Ave. at Loch Raven Blvd., Towson, Baltimore 4, Md.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Hart Mfg. Co., 110 Bartholomew Ave., Hartford 1, Ct.
Johnson Service Co., 507 E. Michigan St., Milwaukee 2, Wis.
Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Penn Elec. Switch Co., Goshen, Ind. *(p. 71)*
Precision Thermometer & Instrument Co., 1442 Brandywine St., Phila. 30, Pa.
Ranco, Inc., 601 W. 5th Ave., Columbus 1, O. *(p. 69)*
Sampsel Time Control, Inc., 600 N. Strong Ave., Spring Valley, Ill.

4CR50

Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Spencer Thermostat Div., Metals & Controls Corp., 34 Forest St., Attleboro, Mass.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
H. A. Thrush & Co., 21 E. Riverside Dr., Peru, Ind.
United Elec. Controls Co., 71 A St., S. Boston 27, Mass.
Wesix Elec. Heater Co., 390-1st St., San Francisco 5, Cal.
Westinghouse Elec. Corp., Meadville, Pa.
White-Rodgers Elec. Co., 1209 Cass Ave., St. Louis 6, Mo.

THERMOSTATS, HOUSEHOLD REFRIGERATOR

Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wis.
Ranco, Inc., 601 W. 5th Ave., Columbus 1, O. *(p. 69)*

THREADED SPECIALTIES (See SCREW MACHINE PARTS)

TIME SWITCHES (See also CONTROLS, PROGRAM, etc.)

Arrow-Hart & Hegeman Elec. Co., 103 Hawthorn St., Hartford 6, Ct.
Automatic Control Co., 1005 University Ave., St. Paul 4, Minn.
Automatic Elec. Mfg. Co., 10 State St., Mankato, Minn.
Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Colloid Equip. Co., Inc., 50 Church St., N.Y.C. 7
R. W. Cramer Co., P.O. Box 25, Centerbrook, Ct. *(p. 194)*
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
Marsh Instrument Co., 3501 Howard St., Skokie, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Paragon Elec. Co., 1600-12th St., Two Rivers, Wis.
Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass.
Reliance Automatic Lighting Co., 1927 Mead St., Racine, Wis.
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
M. H. Rhodes, Inc., 20 Barholomew, Hartford, Ct.
Sampsel Time Control, Inc., 600 N. Strong Ave., Spring Valley, Ill.
C. J. Tagliabue Mfg. Co., 614 Frelinghuysen Ave., Newark 5, N.J.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Tork Clock Co., Inc., 1 Grove St., Mt. Vernon, N.Y.
Wesix Elec. Heater Co., 390-1st St., San Francisco 5, Cal.
White-Rodgers Elec. Co., 1209 Cass Ave., St. Louis 6, Mo.

TIN

Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
National Lead Co., 111 Broadway, N.Y.C. 6
Northwest Lead Co., 2700-6th Ave., S.W., Seattle 4, Wash.

TIN PLATE

Belmont Smelting & Refining Wks., Inc., 330 Belmont Ave., Brooklyn 7, N.Y.
Bethlehem Steel Co., Bethlehem, Pa.
Carnegie-Illinois Steel Corp., U. S. Steel Corp. Subsidiary, Carnegie Bldg., Pittsburgh 30, Pa.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Weirton Steel Co., Weirton, W. Va.
Wheeling Steel Corp., Wheeling, W. Va.
Youngstown Sheet & Tube Co., Youngstown, O.

TRACERS (See LEAK INDICATORS)

TRACK, SLIDING DOOR

American Hard Rubber Co., 11 Mercer St., N.Y.C. 13
Knape & Vogt Mfg. Co., Grand Rapids 4, Mich.
Koch Butchers' Supply Co., 600 E. 14th Ave., N. Kansas City 16, Mo.
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp., 500-5th Ave., N.Y.C. 18

TRACKAGE, OVERHEAD FOR CRANES

American Monorail Co., 13107 Athens Ave., Cleveland 7, O.
Union Mfg. Co., New Britain, Ct.

TRANSFORMERS

American Transformer Co., 172 Emmet St., Newark 5, N.J.
Barber-Colman Co., Rockford, Ill.
Better Coils, Inc., Goodland, Ind.
Dean W. Davis & Co., Kentland, Ind.
Eisler Engrg. Co., Inc., 740 S. 13th St., Newark 3, N.J.
Esterline-Angus Co., Inc., P.O. Box 596, Indpls. 6, Ind.
Forbes & Myers, 173 Union St., Worcester, Mass.
France Mfg. Co., 10325 Berea Rd., Cleveland 2, O.
General Elec. Co., 1 River Rd., Schenectady 5, N.J.
Jefferson Elec. Co., 25 Ave. & Madison St., Bellwood, Ill.

TRAPS, REFRIGERATOR DRAIN

Kason Hardware Corp., 127 Wallabout St., Brooklyn 6, N.Y.

TRAPS, STEAM (See STEAM TRAPS)

TRAPS, WATER, FOR AIR LINES

Armstrong Machine Wks., 831 Maple St., Three Rivers, Mich. *(p. 164)*
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Sarco Co., Inc., 350-5th Ave., N.Y.C. 1 *(p. 173)*
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.

TRAYS, DEFROSTING

Mack Molding Co., Ryerson Ave., Wayne, N.J.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Sneath Glass Co., Hartford City, Ind.

TRAYS, DISPLAY CASE

Bettinger Enamel Corp., Metal Fabricating Div., Waltham, Mass.
Gustar Glaser Co., Inc., 2 Wait St., Paterson 4, N.J.
Ingram-Richardson Co., 32nd St., Beaver Falls, Pa.
McCray Refrigerator Co., Kendallville, Ind.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.

TRAYS, ICE CUBE (See ICE CUBE TRAYS)

TRAYS, WIRE (See also SHELVES; also WIRE FORMING)

Wall Wire Products Co., 11333 General Dr., Plymouth, Mich.
L. A. Young Spring & Wire Corp., 9200 Russell St., Detroit 11, Mich.

TREATMENT, BRINE, WATER, etc. (See BRINE TREATMENT; also WATER TREATMENT; also INHIBITORS)

TRIM, BREAKER (See BREAKER STRIPS)

TRIM, CABINET (See also NAME PLATES)

American Emblem Co., Inc., P.O. Box 116-H, Utica 1, N.Y.
Brasco Mfg. Co., Harvey, Ill.
Croname, Inc., 3701 N. Ravenswood, Chicago 13, Ill.
Dahlstrom Metallic Door Co., 435 Buffalo St., Jamestown, N.Y.
Dearborn Glass Co., 2414 W. 21st St., Chicago 8, Ill.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Grand Rapids Brass Co., 60 Scribner Ave., N.W., Grand Rapids 1, Mich.
Kent Plastics, 1528 N. Fulton Ave., Evansville, Ind.
John Lees Div., Serrick Corp., Muncie, Ind.
Rigidized Metals Corp., 658 Ohio St., Buffalo 3, N.Y.
Sandee Mfg. Co., 5050 W. Foster Ave., Chicago 30, Ill.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Stanley Wks., 195 Lake St., New Britain, Ct.
Amos Thompson Corp., Edinburg, Ind.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
R. D. Werner Co., Inc., 295-5th Ave., N.Y.C. 16

TROLLEYS, OVERHEAD CONVEYOR (See CONVEYORS)

TRUCK & TRAILER BODIES, REFRIGERATED

Divco Corp., 22000 Hoover Rd., Detroit 5, Mich.
Robbins & Burke, Inc., 29 Lansdowne, Cambridge, Mass.
Stokes Co., 131st & Morgan Sts., Blue Island, Ill.

TRUCK & TRAILER REFRIGERATION SYSTEMS

Advance Mfg. Co., Inc., 2700 Buchanan St., Detroit 8, Mich.
American Mfg. Co., Inc., P.O. Box, 989, Montgomery 2, Ala.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Cold Control, Inc., 111 Broadway, N.Y.C. 6
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Fruehauf Trailer Co., 10940 Harper Ave., Detroit 32, Mich.
Industrial Mfg. & Engrg. Co., 3845 N. Ravenswood Ave., Chicago 13, Ill.
Kold-Hold Mfg. Co., 735 E. Hazel St., Lansing 4, Mich.
North American Distributing Corp., 415 Lexington Ave., N.Y.C. 17 *(p. 166)*
Propane Development Corp., 41 Murray St., N.Y.C. 7
Stokes Co., 131st & Morgan Sts., Blue Island, Ill.
U. S. Thermo Control Co., 44 S. 12th St., Minneapolis 4, Minn.

TRUCK CASTERS

Bossick Co., 437 Howard Ave., Bridgeport 2, Ct.
Colson Corp., Cedar St., Elyria, O.
Darnell Corp., Ltd., P.O. Box 4027, Sta. B., Long Beach 4, Cal.
Fairbanks Co., 393 Lafayette, N.Y.C. 3
Menasha Wood Split Pulley Co., 674 Tayco St., Menasha, Wis.
Nutting Truck & Caster Co., Inc., 1125 W. Division St., Fairbault, Minn.

TRUCK PLATES

Central Iron & Steel Co., Harrisburg, Pa.
Dole Refrigerating Co., 5910 N. Pulaski Rd., Chicago 30, Ill.
Kold-Hold Mfg. Co., 735 E. Hazel St., Lansing 4, Mich.

TRUCKS, MATERIAL HANDLING

Colson Corp., Cedar St., Elyria, O.
Fairbanks Co., 393 Lafayette, N.Y.C. 3
Falstrom Co., 13 Falstrom Court, Passaic, N.J.
Menasha Wood Split Pulley Co., 674 Tayco St., Menasha, Wis.
Nutting Truck & Caster Co., Inc., 1125 W. Division St., Fairbault, Minn.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.

TUBE BENDING (See also PIPE COILS, BENDS & BENDING)

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Capitol Mfg. & Supply Co., 153 W. Fulton St., Columbus, O.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
C. F. Moores Co., Inc., Ivy Hill Rd., Wyndmoor, Phila. 18, Pa.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.

TUBE ICE MACHINERY (See ICE MAKING MACHINES)

TUBES & TUBING, ALLOY

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.

(Continued)

TUBES & TUBING, ALLOY (Continued)

Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Copper & Smelting Co., 1862 E. 123rd St., Cleveland 6, O.
National Tube Co., U. S. Steel Corp., Subsidiary, P.O. Box 266, Pittsburgh, Pa.
Ohio Seamless Tube Co., 132 W. Main St., Shelby, O.
Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Cal.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Superior Tube Co., 20 Germantown Ave., Norristown, Pa.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

TUBES & TUBING, ALUMINUM

Aluminum Co. of America, Pittsburgh 19, Pa.
American Brass Co., Waterbury 88, Ct. *(p. 199)*
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Colonial Alloys Co., Ridge Ave. & Crawford St., Phila. 29, Pa.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Linderme Tube Co., 1500 E. 219th St., Cleveland 17, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.

TUBES & TUBING, BRASS & BRONZE

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Lewin Metals Div., Lewin-Mathes Co., 1111 Chouteau, St. Louis, Mo.
Linderme Tube Co., 1500 E. 219th St., Cleveland 17, O.
MacKenzie-Walton Co., 480 Pawtucket Ave., Pawtucket, R.I.
National Copper & Smelting Co., 1862 E. 123rd St., Cleveland 6, O.
Penn Brass & Copper Co., Powell Ave., Erie, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
Shenango-Penn Mold Co., Dover, O.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.
Wolverine Tube Div., Calumet & Hecla Cons. Copper Co 1411 Central Ave., Detroit 9, Mich.

TUBES & TUBING, CAPILLARY

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Bundy Tubing Co., E. Jefferson & Parker Ave., Detroit 4, Mich. *(p. 201)*
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
MacKenzie-Walton Co., 480 Pawtucket Ave., Pawtucket, R.I.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Copper & Smelting Co., 1862 E. 123rd St., Cleveland 6, O.
Penn Brass & Copper Co., Powell Ave., Erie, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Superior Tube Co., 20 Germantown Ave., Norristown, Pa.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.
Wabash Mfg. Co., 2642 S. Michigan Ave., Chicago 16, Ill.
Wolverine Tube Div., Calumet & Hecla Cons. Copper Co., 1411 Central Ave., Detroit 9, Mich.

TUBES & TUBING, CAPILLARY (ASSEMBLIES)

Allin Mfg. Co., 1153 W. Grand Ave., Chicago, Ill.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Wabash Mfg. Co., 2300 South Western Ave., Chicago 8, Ill.

TUBES & TUBING, COPPER

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Lewin Metals Div., Lewin-Mathes Co., 1111 Chouteau, St. Louis, Mo.
Linderme Tube Co., 1500 E. 219th St., Cleveland 17, O.
MacKenzie-Walton Co., 480 Pawtucket Ave., Pawtucket, R.I.
Mueller Brass Co., Port Huron, Mich.
National Copper & Smelting Co., 1862 E. 123rd St., Cleveland 6, O.
Penn Brass & Copper Co., Powell Ave., Erie, Pa.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 *(p. 197)*
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.
Viking Copper Tube Co., 16700 St. Clair Ave., Cleveland 10, O.
Wolverine Tube Div., Calumet & Hecla Cons. Copper Co., 1411 Central Ave., Detroit 9, Mich.

TUBES & TUBING, FIBRE (See FIBRE, SHEET, ROD & TUBE)

TUBES & TUBING, INCONEL, MONEL, NICKEL

Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Bundy Tubing Co., E. Jefferson & Parker Ave., Detroit 4, Mich. *(p. 201)*
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Driver-Harris Co., Harrison, N.J.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
Haynes Stellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
International Nickel Co., 67 Wall St., N.Y.C. 5
MacKenzie-Walton Co., 480 Pawtucket Ave., Pawtucket, R.I.
National Tube Co., U. S. Steel Corp., Subsidiary, P.O. Box 266, Pittsburgh, Pa.
Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Cal.
Superior Tube Co., 20 Germantown Ave., Norristown, Pa.

TUBES & TUBING, RUBBER

Continental Rubber Wks., 2000 Liberty St., Erie, Pa.
Flexible Tubing Corp., N. Main St., Bramford, Ct.
Garlock Packing Co., 402 E. Main St., Palmyra, N.Y.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Quaker Rubber Corp., Tacony & Milnor Sts., Phila. 24, Pa.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Stokes Molded Products, Inc., Taylor at Webster St., Trenton 4, N.J. (Hard Rubber)
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

TUBES & TUBING, SPONGE RUBBER

P. F. Goodrich Co., 500 S. Main St., Akron, O.

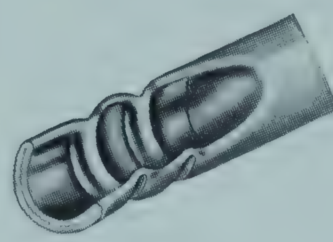
(Continued)

REVERE DRYSEAL COPPER REFRIGERATION TUBE

NEW Package

Revere Dryseal Tube now comes in 50-foot double layer flat coils, packed in cartons. These new red and blue cartons protect the tube, keep it clean, may be conveniently stacked for storage, and are easier to identify and to unpack.

NEW Seal



Revere Dryseal Tube now has a double-groove mechanical seal. It is compact enough to pass through any opening large enough for the tube itself. It permanently keeps the interior of the tube clean and bone dry.

NEW Standards

Revere Dryseal Tube now comes in new, more economical dimensional standards as follows:

Size O.D. in inches	Wall Gauge in inches	Pounds per Linear Foot	Approx. Weight per 50-ft. Coil
1/8	.030	.0347	1.74
3/16	.030	.0575	2.88
1/4	.030	.0804	4.02
5/16	.032	.109	5.45
3/8	.032	.134	6.70
1/2	.032	.182	9.10
5/8	.035	.251	12.55
3/4	.035	.305	15.25

Revere Dryseal is the Standard of Quality

Revere Dryseal Tube is dead soft, so that you can bend it easily . . . and the ends won't split when flared. Exterior and interior surfaces are clean, smooth, and free from mechanical defects. It is made of deoxidized copper (99.9% pure) and is kept oxide-free by special processing methods.

Revere Dryseal Copper Refrigeration Tube and Revere Aluminum Refrigeration Tube are available from leading distributors throughout the country.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

230 Park Avenue, New York 17, New York

Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N.Y.—

Sales Offices in Principal Cities, Distributors Everywhere

TUBES & TUBING, SPONGE RUBBER (Continued)

Hewitt-Robins, Inc., 240 Kensington Ave., Buffalo 5, N.Y.
Jarrow Products, 420 N. La Salle St., Chidago 10, Ill. (*p. 83*)
Sponge Rubber Products Co., 106 Derby Place, Shelton, Ct.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

TUBES & TUBING, STEEL

Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Bethlehem Steel Co., Bethlehem, Pa.
Bundy Tubing Co., E. Jefferson & Parker Ave., Detroit 4, Mich. (*p. 201*)
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
Jones & Laughlin Steel Co., Pittsburgh, Pa.
Laclede Steel Co., Arcade Bldg., St. Louis 1, Mo.
Michigan Seamless Tube Co., S. Lyon, Mich.
Michigan Steel Tube Products Co., 9450 Buffalo St., Detroit 12, Mich.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J
National Tube Co., U. S. Steel Corp. Subsidiary, P. O. Box 266, Pittsburgh, Pa.
Ohio Seamless Tube Co., 132 W. Main St., Shelby, O.
Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Cal.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 (*p. 197*)
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Superior Tube Co., 20 Germantown Ave., Norristown, Pa.

TUBES & TUBING, STEEL, STAINLESS

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Carpenter Steel Co., Reading, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Cherry-Burrell Corp., 427 W. Randolph St., Chicago 6, Ill.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Tube Co., U. S. Steel Corp. Subsidiary, P.O. Box 266, Pittsburgh, Pa.
Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Cal.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Superior Tube Co., 20 Germantown Ave., Norristown, Pa.
Wallace Tube Co., Sub. of Wallace Supplies Mfg. Co., 1300 Diversey Pkwy., Chicago 14, Ill.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.

TUBES, BOILER & CONDENSER

American Brass Co., Waterbury 88, Ct. (*p. 199*)
Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Bethlehem Steel Co., Bethlehem, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Columbia Steel & Shafting Co., P.O. Box 1577, Pittsburgh 30, Pa.
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Tube Co., U. S. Steel Corp. Subsidiary, P.O. Box 266, Pittsburgh, Pa.
Ohio Seamless Tube Co., 132 W. Main St., Shelby, O.
Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Cal.
Pittsburgh Pipe Coil & Bending Co., 61 Bridge St., Etna P.O., Pittsburgh 23, Pa.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 17 (*p. 197*)
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Superior Tube Co., 20 Germantown Ave., Norristown, Pa.
Wolverine Tube Div., Calumet & Hecla Cons. Copper Co., 1411 Central Ave., Detroit 9, Mich.

TUBING, BEER

Aeroquip Corp., 300 S. East Ave., Jackson, Mich.
Bundy Tubing Co., E. Jefferson & Parker Ave., Detroit 4, Mich. (*p. 201*)
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Hudson Products Co., Inc., 4400 St. Aubin, Detroit 7, Mich.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.

TUBING, BLOCK TIN

Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
National Lead Co., 111 Broadway, N.Y.C. 6
Northwest Lead Co., 2700-16th Ave., S.W., Seattle 4, Wash.

TUBING, FINNED (See FINNED TUBING)

TUBING, FLEXIBLE METAL (See also CHARGING LINES; also FLEXIBLE CONNECTIONS)

Aeroquip Corp., 300 S. East Ave., Jackson, Mich.
American Brass Co., Waterbury 88, Ct. (*p. 199*)
Atlantic Metal Hose Co., Inc., 123 W. 64th St., N.Y.C. 23
Chicago Metal Hose Corp., Maywood, Ill.
Eclipse Aviation Metal Hose Dept., Div. of Bendix Aviation Corp., Phila. 44, Pa.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Federal Metal Hose Corp., 277 Military Rd., Buffalo 7, N.Y.
Flexible Tubing Corp., N. Main St., Branford, Ct.
Johnson Metal Hose Co., 226 Mill St., Waterbury 88, Ct.
Resistoflex Corp., 39 Plansoen St., Belleville 9, N.Y.
Seamlex Co., Inc., 4123-24th St., Long Island City 1, N.Y.
Titeflex, Inc., 500 Frelinghuysen Ave., Newark 5, N.J.
Uniflex Metal Hose Co., 52 Rubber Ave., Naugatuck, Ct.

TUBING, LEAD

Bridgeport Thermostat Co., Inc., 1225 Connecticut Ave., Bridgeport 1, Ct.
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
National Lead Co., 111 Broadway, N.Y.C. 6
Northwest Lead Co., 2700-16th Ave., S.W., Seattle 4, Wash.

TUBING, LIGHT WALL

American Brass Co., Waterbury 88, Ct. (*p. 199*)
W. R. Ames Co., 150 Hooper St., San Francisco 7, Cal.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Laclede Steel Co., Arcade Bldg., St. Louis 1, Mo.
MacKenzie-Walton Co., 480 Pawtucket Ave., Pawtucket, R.I.
Michigan Seamless Tube Co., S. Lyon, Mich.
Michigan Steel Tube Products Co., 9450 Buffalo St., Detroit 12, Mich.
National Copper & Smelting Co., 1862 E. 213rd St., Cleveland 6, O.
Ohio Seamless Tube Co., 132 W. Main St., Shelby, O.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C. 7 (*p. 197*)

ANACONDA PRODUCTS FOR THE REFRIGERATION INDUSTRY

ANACONDA COPPER REFRIGERATION TUBES have qualities that assure a dependable, ready-and-easy-to-use refrigeration tube:

. . . they are dehydrated to eliminate troublesome moisture.

. . . they come to you in single-coil cartons with unusually clean and bright inside surfaces.

. . . the exclusive Anaconda Cup Seal reduces waste and protects the inside of the tube from the point of manufacture to the point of installation.

. . . they are uniformly soft, easy to bend and may be readily flared without cracking.

Anaconda Refrigeration Tubes are 99.9% pure copper, made to A.S.T.M. Specification B68. They are available in all standard sizes up to and including ¾″ O.D. in 50-foot coils. Longer lengths on special order.

PRECISION-MADE TUBES in Copper, Brass, Bronze and Copper-Nickel Alloys; in sizes from 0.15″ O.D. to 1″ O.D. with wall thickness down to .004″ round, square, or irregularly shaped.

RESTRICTOR TUBE

FORMED TUBE PARTS

HARD COPPER TUBE
CUT TO LENGTH

COPPER WATER TUBE IN COILS
AND STRAIGHT LENGTHS—
TYPES K AND L

TUBE FITTINGS

VIBRATION ELIMINATORS

CHARGING HOSE

FLEXIBLE REFRIGERATION
TUBING CONDUIT

DIE PRESSED FORGINGS

COPPER, BRASS, BRONZE IN SHEETS, WIRE, RODS, TUBES AND SPECIAL SHAPES

THE AMERICAN BRASS COMPANY, General Offices: Waterbury 20, Connecticut

In Canada: New Toronto, Ontario

TUBING, LOCK SEAM

Brasco Mfg. Co., Harvey, Ill.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.

TUBING, MECHANICAL

Babcock & Wilcox Co., 85 Liberty St., N.Y.C. 6
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Columbia Steel & Shafting Co., P.O. Box 1557, Pittsburgh 30, Pa.
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Globe Steel Tubes Co., 3839 W. Burnham, Milwaukee 4, Wis.
Michigan Seamless Tube Co., S. Lyon, Mich.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Tube Co., U. S. Steel Corp. Subsidiary, P.O. Box 266, Pittsburgh, Pa.
Ohio Seamless Tube Co., 132 W. Main St., Shelby, O.
Pittsburgh Tube Co., 323-4th Ave., Pittsburgh 22, Pa.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Superior Tube Co., 20 Germantown Ave., Norristown, Pa.

TUBING, PREFABRICATED

Bundy Tubing Co., E. Jefferson & Parker Ave., Detroit 4, Mich. *(p. 201)*
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Everhot Products Co., 2001 Carroll Ave., Chicago 12, Ill.
Fitzsimons Mfg. Co., 3775 E. Outer Dr., Detroit 12, Mich.
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Kenmore Machine Products, Inc., 15 Depew Ave., Lyons, N.Y.
Mueller Brass Co., Port Huron, Mich.
A. B. Murray Co., Inc., 630 Green Lane, Elizabeth, N.J.
National Copper & Smelting Co., 1862 E. 123rd St., Cleveland 6, O.
Ohio Seamless Tube Co., 132 W. Main St., Shelby, O.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.

Edw. Renneburg & Sons Co., 2639 Boston St., Baltimore 24, Md.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Wolverine Tube Div., Calumet & Hecla Cons. Copper Co., 1411 Central Ave., Detroit 9, Mich.

TUBULAR PARTS

Michigan Steel Tube Products Co., 9450 Buffalo St., Detroit 12, Mich.
Mueller Brass Co., Port Huron, Mich.
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
Ohio Seamless Tube Co., 132 W. Main St., Shelby, O.
Republic Steel Corp., Steel & Tubes Div., 224 E. 131st St., Cleveland, O.
Wolverine Tube Div., Calumet & Hecla Cons. Copper Co., 1411 Central Ave., Detroit 9, Mich.

TUNNEL FREEZERS (See FREEZERS)

TURBINES (See STEAM TURBINES)

TURBO COMPRESSORS (See also COMPRESSORS, CENTRIFUGAL; also CONDENSING UNITS, CENTRIFUGAL)

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Ingersoll-Rand Co., 11 Broadway, N.Y.C. 4
Roots-Connersville Blower Corp., P.O. Box 327, Connersville, Ind.
Spencer Turbine Co., Hartford 6, Ct.
Trane Co., La Crosse, Wis. *(p. 12)*
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

TURNBUCKLES

Bethlehem Steel Co., Bethlehem, Pa.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
U. S. Expansion Bolt Co., York, Pa.

TURNINGS (See SCREW MACHINE PARTS; also THREADED SPECIALTIES)

TWO TEMPERATURE VALVES, SNAP ACTION (See also SUCTION PRESSURE REGULATING VALVES)

Alco Valve Co., 855 Kingsland Ave., St. Louis 5, Mo. *(p. 95)*
Aminco Refrigeration Products Co., 14544-3rd Ave., Detroit 3, Mich. *(p. 149)*
Automatic Products Co., 2450 N. 32nd St., Milwaukee 10, Wis. *(p. 96)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.

ULTRA-VIOLET RADIATION (See also LAMPS, BACTERICIDAL)

Alexander-Tagg Industries, Inc., Jacksonville Rd. & Summit Ave., Hatboro, Pa.
Hanovia Chemical & Mfg. Co., Chestnut St. & N.J.R.R. Ave., Newark 5, N.J.
Reynolds Elec. Co., 2650 W. Congress, Chicago 12, Ill.
Sperti, Inc., Norwood Sta., Cin'ti. 12, O.
Ultra-Violet Products, Inc., 145 Pasadena Ave., S. Pasadena, Cal.

UNDERCOATERS (See COATINGS & COMPOUNDS; also FINISHES)

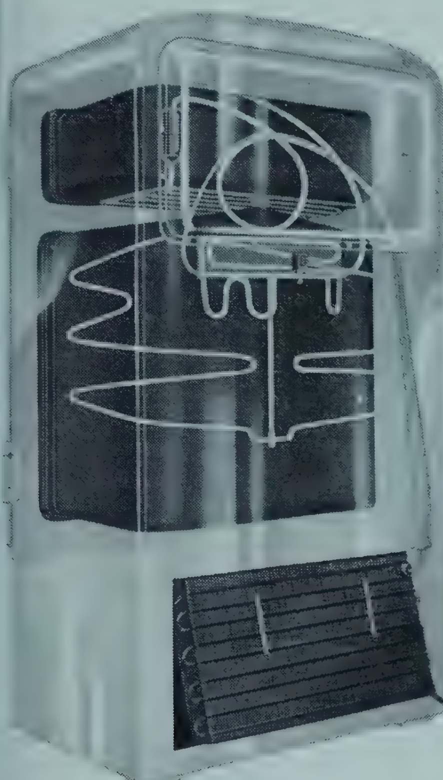
UNIONS, PIPE (See FITTINGS, PIPE)

UNIT COOLERS ABOVE 32°—CEILING MOUNTED (A—Ammonia; B—Other refrigerants)

(A,B) Advanced Engrg. Co., 2646 W. Fond du Lac Ave, Milwaukee, Wis.
(B) American Coils Co., 25 Lexington St., Newark 5, N.J.

(Continued)

Know *why* Bundyweld is better refrigeration tubing?



Easy . . . because Bundyweld offers you more plus refrigeration values than any other tubing.

And we mean *more!* Bundyweld's made by a patented process . . . double-walled from a single strip. That means extra strength for extra durability in your products.

Bundyweld is more leakproof, too, *by test,* than practically any other type tubing! Halogen vapor leak-detectors prove Bundyweld's walls are extra-tight.

Bundyweld's faster-cooling as well! Its specially constructed walls, though stronger, are actually thinner . . . *and thinner walls mean faster cooling!*

More, Bundyweld is ductile, yet it won't collapse or weaken structurally. Each Bundyweld feature brings better performance to products, savings to you. Get the complete story; contact a distributor, or write: ***Bundy Tubing Company, Detroit 14, Michigan.***

Bundyweld® Tubing

SIZES UP TO ⅝" O. D.

DOUBLE-WALLED FROM A SINGLE STRIP

WHY BUNDYWELD IS BETTER TUBING

Bundyweld starts as a single strip of basic metal, coated with a bonding metal. Then it's . . . continuously rolled twice around laterally into a tube of uniform thickness, and passed through a furnace. Bonding metal fuses with basic metal, presto— Bundyweld . . double-walled and brazed through 360° of wall contact.

Bundy Tubing Distributors and Representatives: ***Cambridge 42, Mass.:*** Austin-Hastings Co., Inc., 226 Binney St. • ***Chattanooga 2, Tenn.:*** Peirson-Deakins Co., 823-824 Chattanooga Bank Bldg. • ***Chicago 32, Ill.:*** Lapham-Hickey Co., 3333 W. 47th Place • ***Elizabeth, New Jersey:*** A. B. Murray Co., Inc., Post Office Box 476 • ***Philadelphia 3, Penn.:*** Rutan & Co., 404 Architects Bldg. • ***San Francisco 10, Calif.:*** Pacific Metals Co., Ltd., 3100 19th St. • ***Seattle 4, Wash.:*** Eagle Metals Co., 3628 E. Marginal Way • ***Toronto 5, Ontario, Canada:*** Alloy Metal Sales, Ltd., 881 Bay St. • **Bundyweld Nickel and Monel Tubing is sold by distributors of Nickel and Nickel alloys in principal cities.**


KRAMER . . .
Products
PANEL UNIT
RADIAL
CURVETTE
EVAPORATIVE CONDENSER
COOLMASTER
DOUBLE DISCHARGE
UNICON
Only
THERMOBANK
by KRAMER
Keeps Coils Frost-Free
Automatically
at Any Temperature
without..
LABOR
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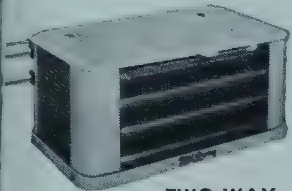
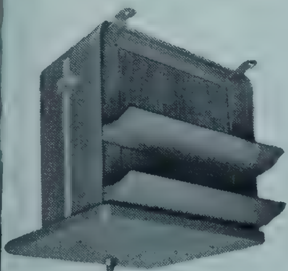
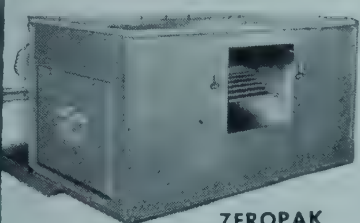
BRINE OR WATER SPRAYS
KRAMER TRENTON CO. Trenton 5, N. J.



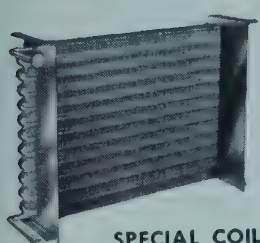
TWO-WAY UNIT COOLER



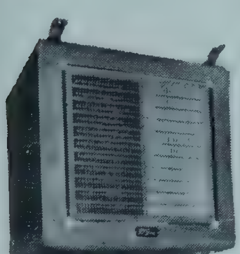
PACEMAKER UNIT COOLER



ZEROPAK Model "L"



SPECIAL COIL



COMFORT COOLER

Two-Way Unit Coolers. A small compact unit designed for reach-ins, back bars, and direct draw bars where space is limited. All connections are on the outside for ease of valve mounting.

Radial Unit Coolers. A unit styled for use where minimum depth and height are required, It may be used for either refrigeration or comfort cooling applications.

Pacemaker Unit Coolers. An ideal unit for walk-in coolers, back bars, etc. Constructed for long life and service free operation.

Panel Type Chillators. A modern attractive unit especially adaptable for wall mounting in reach-in cabinets and small low ceiling walk-ins.

Model "X" Zeropak. Developed primarily for locker plants as an efficient cooler and sharp freezer combined. This unit has been found very suitable for all types of low temperature storage.

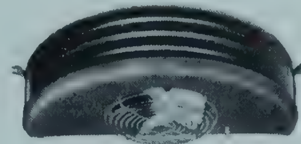
Model "L" Zeropak. The leader in the low temperature field for locker plants, meat freezing rooms, and ice cream hardening rooms. Types "C" and "CA" storage coolers for extra heavy product loads in large rooms above 35°F are also available.

Multi Louvre Coils. For use where high humidity and slow uniform air movement is required, as in floral boxes or cheese rooms.

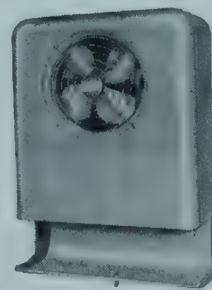
Special Coils. All types of special coils such as heavy duty evaporators and condensers for refrigerated trucks, rail cars, etc., as well as ⅜" tube evaporators and condensers for light tonnage applications.

Comfort Coolers. An attractive unit readily installed without extensive building alterations. Available for freon or chilled water. Chilled water units may also be used for hot water or steam for year round use in taverns, beauty shops, and restaurants.

RH Air Conditioners. This unit may be installed in the conditioned space or in an adjacent area with or without duct work. In addition to the freon coil they are available with water and steam coils for year round application.

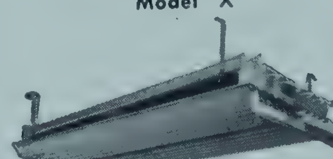


RADIAL UNIT COOLER



CHILLATOR (Panel Type)

ZEROPAK Model "X"



MULTI-LOUVRE COIL

RH AIR CONDITIONER

Descriptive bulletins on all McQuay products available upon request

McQuay, Inc.

1600 Broadway, N.E., Minneapolis 13, Minn.

Manufacturers of Equipment for All Phases of Air Conditioning

UNIT COOLERS ABOVE 32°—CEILING MOUNTED (Continued)

(A,B) Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
(B) Betz Corp., 445 State St., Hammond, Ind.
(A,B) Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
(A,B) Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. *(p. 200)*
(A,B) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
(A,B) Conditionaire Unit Co., Div. of Howe Ice Machine Co., 2815 Montrose Ave., Chicago 18, Ill. *(p. 204)*
(B) Curtis Refrigerating Machine Div., Curtis Mfg. Co., 2815 Montrose Ave., Chicago 18, Ill. *(p. 49)*
(A,B) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(B) Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(B) Fedders-Quigan Corp., 57 Tonawanda St., Buffalo 7, N.Y. *(p. 53)*
(B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(A,B) Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
(B) General Elec. Co., Air Conditioning Dept., 5 Lawrence St., Bloomfield, N.J. *(p. 66)*
(A,B) Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. *(p. 204)*
(A,B) Industrial Mfg. & Engrg. Co., 3845 N. Ravenswood Ave., Chicago 13, Ill.
(A,B) Kennard Corp., 1819 S. Hanley Rd., St. Louis 17, Mo. *(p. 14)*
(A,B) King Co., 902 N. Cedar St., Owatonna, Minn.
(A) Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. *(p. 202)*
(A,B) Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. *(p. 209)*
(B) McCord Corp., Riopelle & E. Grand Blvd., Detroit 11, Mich. *(p. 37)*
(A,B) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
(A,B) Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. *(p. 205)*
(A,B) D. J. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
(A,B) Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
(A,B) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(A,B) Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B) Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
(A,B) Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
(A,B) Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
(A,B) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
(A,B) St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
(A,B) Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
(B) Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) Trane Co., La Crosse, Wis. *(p. 12)*
(A,B) U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(A,B) Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
(A,B) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,B) York Corp., York, Pa. *(p. 119)*

UNIT COOLERS ABOVE 32°—FLOOR MOUNTED (A—Ammonia; B—Other refrigerants)

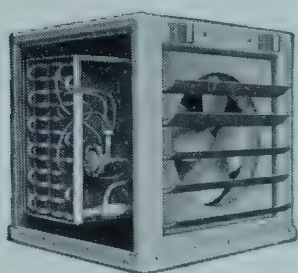
(A,B) Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
(A.B) Baker Refrigration Corp., S. Windham, Me. *(p. 48)*
(B) Betz Corp., 445 State St., Hammond, Ind.
(A,B) Buffalo Forge Co., 217 Mortimer St., Buffalo) 10, N.Y. *(p. 93)*
(A,B) Bush Mfg. Co., 179 South St., W. Hartford 10, 10, Ct. *(p. 200)*
(A,B) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
(A,B) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(B) Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(A,B) Frick Co., Waynesboro, Pa. *(p. 44)*
(B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(A,B) Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
(A,B) Howe Machine Co., 2825 Montrose Ave., Chicago 18, Ill. *(p. 204)*
(A,B) Kennard Corp., 1819 S. Hanley Rd., St. Louis 17, Mo. *(p. 14)*
(A,B) King Co., 902 N. Cedar St., Owatonna, Minn.
(A) Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. *(p. 202)*
(A,B) Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. *(p. 209)*
(A,B) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
(A,B) Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. *(p. 205)*
(A,B) Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
(A,B) Peerless Of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(A,B) Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B) Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
(A,B) Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
(A,B) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
(A) St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.

(Continued)

Marlo

Industrial Coolers—Unit Coolers—Evaporative Condensers—Low Temperature Units—Air Conditioning Units—Heating and Cooling Coils—Cooling Towers—Diesel Engine and Oil Evaporative Coolers

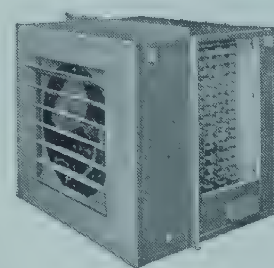
Quality Heat Transfer Equipment Since 1925



UNIT COOLER—DUC

UNIT COOLERS—UC AND DUC

11 unit sizes—675 to 4160 cfm. Blow-through and Pull-through types. *Write for Bulletins 392 and 412.*

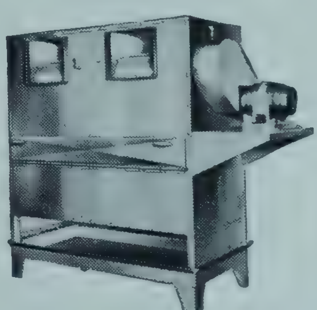


ELECTRIC DEFROST LT UNITS

(U.S. Patent 2266373) 7 sizes—Ammonia or Freon—½ to 2½ tons at 12 deg. TD. *Bulletin 408*

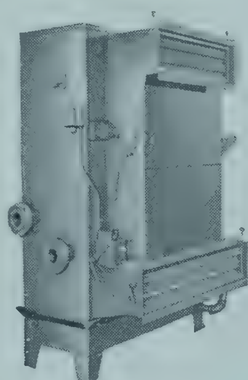
BLAST COILS

Air conditioning—Industrial Refrigeration—Heating. Any material—All refrigerants—Every application. Pressure-expanded staggered tubes, continuous plate-type fins. *Bulletin 396.*



INDUSTRIAL COOLERS

15 unit sizes—1000 to 26,400 cfm—Floor type. Dry Coil and Spray types. *Bulletin 403.*



EVAPORATIVE DIESEL COOLER

25 HP to 4000 HP

EVAPORATIVE CONDENSERS

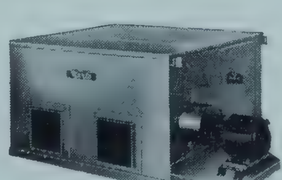
3 to 100 tons—All refrigerants—All prime surface coils—No fins—Quiet—Motor Uni-drive. Indoor or outdoor units—Durable construction. *Bulletin 404.*

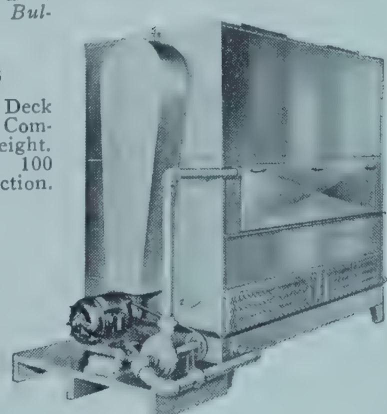
AIR CONDITIONING UNITS

Cooling — Heating — Dehumidifying — Humidifying. 14 sizes—1 to 150 tons—640 to 37,200 cfm. Ceiling suspended or floor types. *Bulletin 409.*

COOLING TOWERS

Induced Draft—Wetted Deck Surface—Water Spray. Compact in space and weight. Outdoor—Indoor—3 to 100 tons. Sectional construction. *Write for Bulletin 406.*





MARLO = HEAT TRANSFER
Since 1925

Marlo COIL CO. • 6135 Manchester Rd. • St. Louis 10, Mo.

UNIT COOLERS ABOVE 32°—FLOOR MOUNTED (Continued)

(A,B) Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) Trane Co., La Crosse, Wis. (*p. 212*)
(A,B) U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (*p. 43*)
(A,B) Worthington Pump & Machinery Corp., Harrison, N.J. (*p. 116*)
(A,B) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,B) York Corp., York, Pa. (*p. 119*)

UNIT COOLERS ABOVE 32°—WALL MOUNTED

(A—Ammonia; B—Other refrigerants)

(B) American Coils Co., 25 Lexington St., Newark 5, N.J
(A,B) Baker Refrigeration Corp., S. Windham, Me. (*p. 48*)
(B) Betz Corp., 445 State St., Hammond, Ind.
(A,B) Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. (*p. 93*)
(B) Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. (*p. 200*)
(B) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (*p. 45*)
(A,B) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(B) Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(B) Fedders-Quigan Corp., 57 Tonawanda St., Buffalo 7, N.Y. (*p. 53*)
(B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. (*p. 6*)
(B) Kennard Corp., 1819 S. Hanley Rd., St. Louis 7, Mo. (*p. 14*)
(A) Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. (*p. 202*)
(A,B) Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. (*p. 209*)
(B) McCord Corp., Riopelle & E. Grand Blvd., Detroit 11, Mich. (*p. 37*)
(B) McCray Refrigerator Co., Kendallville, Ind.
(A,B) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. (*p. 203*)
(A,B) Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. (*p. 205*)
(A,B) D. J. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
(A,B) Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 (*p. 91*)
(A,B) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(B) Reese & Long Refrigeration Products, Inc., 408 E 25th St., N.Y.C. 10
(A,B) Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B) Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. (*p. 207*)
(A,B) Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. (*p. 211*)
(A,B) Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
(A,B) St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
(B) Sterling Mfg. Co., 2523 Farnam St., Omaha, Neb.
(A,B) Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
(B) Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(B) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B) U. S. Air Conditioning Corp., Como Ave., S.E., at 33rd St., Minneapolis 14, Minn.
(A,B) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (*p. 43*)
(A,B) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

UNIT COOLERS BELOW 32°—CEILING MOUNTED

(A—Ammonia; B—Other refrigerants)
(a—Reverse cycle; b—Electric; c—Brine spray; d—Water; e—Glycol; f—Warm air; g—Others)

(B:b) American Coils Co., 25 Lexington St., Newark 5, N.J.
(A,B:a,c,e) Baker Refrigeration Corp., S. Windham, Me. (*p. 48*)
(B:d) Betz Corp., 445 State St., Hammond, Ind.
(A,B:f) Buffalo Forge Co., 217 Mortimer St., Buffalo N.Y. (*p. 93*)
(A,B:b,d) Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. (*p. 200*)
(A,B:d) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (*p. 45*)
(B:d) Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1949 Kienlen Ave., St. Louis 20, Mo. (*p. 49*)
(A,B:a,b,c,d) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
Evans Mfg. Corp., 460 S. 10th St., Mt. Vernon, N.Y.
(B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. (*p. 6*)
A,B:a,b,d,c) Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
(A,B:a,d) Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. (*p. 204*)
(d,f) King Co., 902 N. Cedar St., Owatonna, Minn.
(a) Kramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. (*p. 202*)
(A,B:d) Larkin Coils, 519 Memorial Dr., S.E., Atlanta 1, Ga. (*p. 209*)
A,B:b) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. (*p. 203*)
(A,B:b) Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. (*p. 205*)
(A,B) D. J. Murray Mfg. Co., 1024-3rd Ave., Wausau, Wis.
(A,B:e) Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 (*p. 91*)
(A,B:b) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(A,B:a,b,c,d) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(A,B:a,b,d) Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B:a,b,c,d) Refrigeration Economics Co., Inc., 1231 Tuscarawas St., Canton 4, O. (*p. 207*)
(A,B:d) Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. (*p. 211*)
(A,B:a) Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
(A,B:c,d) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
(A,B:a,b,c,d,e,f,g) St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(g) Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.
(B:d,e,g) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B:a,c) Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. (*p. 43*)
(c,e) Worthington Pump & Machinery Corp., Harrison, N.J. (*p. 116*)
(A,B:a,c,d,f) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,B) York Corp., York, Pa. (*p. 119*)

UNIT COOLERS BELOW 32°—FLOOR MOUNTED

(A—Ammonia; B—Other refrigerants)
(a—Reverse cycle; b—Electric; c—Brine spray; d—Water; e—Glycol; f—Warm air; g—Other)

(A,B:c) Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. (*p. 219*)
(A,B:a,c,e) Baker Refrigeration Corp., S. Windham, Me. (*p. 48*)
(B:d) Betz Corp., 445 State St., Hammond, Ind.
(A,B:f) Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. (*p. 93*)
(A,B:d) Bush Mfg. Co., 179 South St., W. Hartford 10, Ct. (*p. 200*)
(A,B:d) Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. (*p. 45*)
(A,B:a,b,c,d) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(A,B:a,c,d,f) Frick Co., Waynesboro, Pa. (*p. [illegible]*)
(B) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. (*p. 6*)
(A,B:a,b,c,d) Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
A,B:a,d) Howe Ice Machine Co., 2825 Montrose Ave., Chicago 18, Ill. (*p. 204*)

(*Continued*)

Refrigeration Economics Co., Inc.

1231 Tuscarawas St. E., Canton 2, Ohio

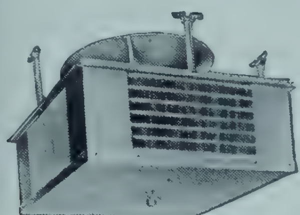
Recoy Products

← C. T. COILS

Continuous-tube down-draft fin-coils are still unsurpassed for meat coolers, or other products requiring high humidity and gentle air circulation.

EVAPORATIVE CONDENSERS →

Evaporative condensers from 2 to 100 tons. Brine spray cooling to 25 tons.

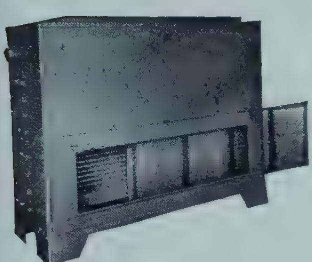


← CEILING DIFFUSER

Ceiling diffusers distribute the cooled air across the ceiling, so the draft does not strike the products stored or occupants.

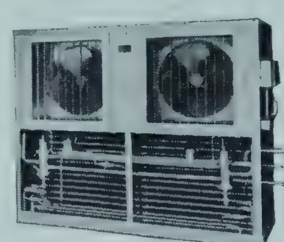
C. F. COILS →

Continuous fin coils for unit coolers, blast heaters, air conditioning and condensers.



← AIR CONDITIONING

Air conditioning units of ceiling or floor type in all capacities, for cooling, heating, or both.



AUTOMATIC DEFROST UNITS →

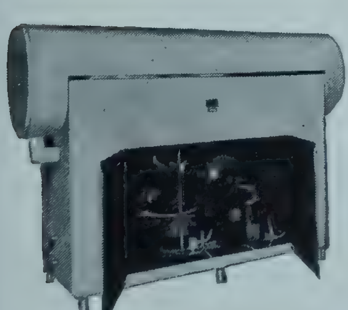
Complete, ready for electric, liquid, suction, and hot gas connections. One coil working always, both 98 per cent of time.

← WALL UNITS

Recoy "All Seasons" wall units provide a damper for deflecting the cold air down along the wall or out horizontally into the room, thus providing proper air circulation for "All Seasons."

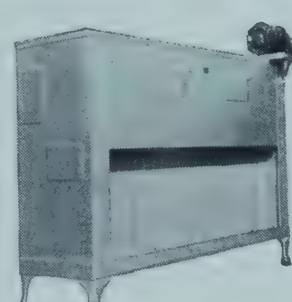
SHELL CONDENSER →

Shell and tube, also shell and fin coil condensers. Both types have tubes arranged for cleaning with mechanical tube cleaner.



← WATER COOLING

Self contained complete ice water and brine coolers complete with high and low sides, circulating pumps, controls, and insulation. 3 to 30 hp.



FLOOR UNITS →

Floor units with cooling surface exposed to view have a definite advantage over those with coils hidden. Design permits water defrosting.

UNIT COOLERS BELOW 32°—FLOOR MOUNTED (Continued)

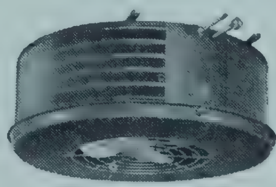
(A,B:d) **McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn.** *(p. 203)*
(A,B:c) **Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo.** *(p. 205)*
(A,B:e) **Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17** *(p. 91)*
(A,B:b) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 15, Ill.
(A,B:a,b,c,d) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(A,B:a,b,c,d) Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B:b,c,d) **Refrigeration Economics Co., Inc., 1231 E. Tuscarawas, St., Canton 4, O.** *(p. 207)*
(A,B:d) **Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal.** *p. (211)*
(A,B:c,d) Rigidbilt, Inc., 2850 W. Fulton St., Chicago 12, Ill.
(A,B:a,b,c,d,e,f,g) St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
(g) Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.
(A,B:d) Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
(d) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B:a,c) **Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis.** *(p. 43)*
(c,e) **Worthington Pump & Machinery Corp., Harrison, N.J.** *(p. 116)*
(A,B:a,c) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
(A,B:c) **York Corp., York, Pa.** *(p. 119)*

LOOK to LARKIN

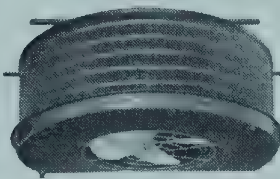
• For Temperature and Humidity Control

IN WALK-IN, REACH-IN REFRIGERATORS, COLD STORAGE ROOMS AND MANY OTHER COMMERCIAL AND INDUSTRIAL APPLICATIONS.

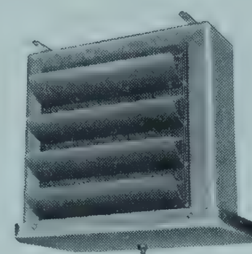
WALL HUMI-TEMP



TURRET HUMI-TEMP



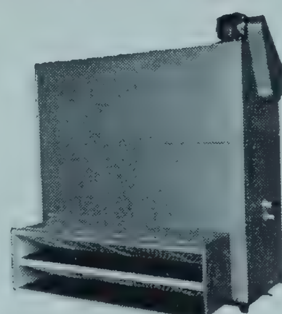
HALF-TURRET HUMI-TEMP



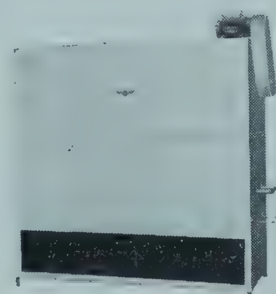
STANDARD HUMI-TEMP

• For Air Conditioning Equipment

COOLING TOWERS & EVAPORATIVE CONDENSERS



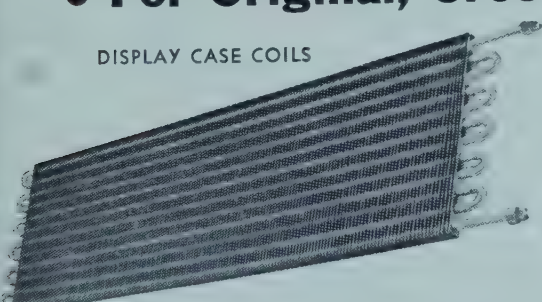
AIR CONDITIONING UNITS

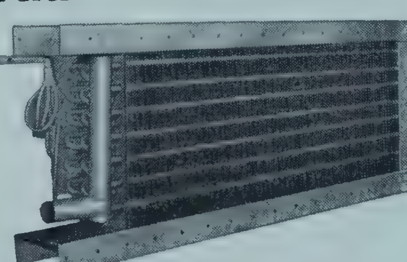


FLOOR HUMI-TEMP UNITS

• For Original, Cross-Fin Aluminum Coils

DISPLAY CASE COILS





AIR CONDITIONING COILS

Manufacturers of the original Cross-Fin Coil—Humi-Temp Units—Evaporative and Air Cooled Condensers—Cooling Towers—Air Conditioning Units—Direct Expansion Water Coolers—Steel Vacuum Coils—Heat Exchangers.

LARKIN COILS INC.

519 MEMORIAL DR., S.E. • ATLANTA, GA.

THE WATCHDOG OF THE NATION'S FOOD SUPPLY

UNIT COOLERS BELOW 32°—WALL MOUNTED

(A—Ammonia; B—Other refrigerants)
(a—Reverse cycle; b—Electric; c—Brine spray; d—Water; e—Glycol; f—Warm air; g—Other)

(B:b) American Coils Co., 25 Lexington St., Newark 5, N.J.
(A,B:a,c,e) Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
(B:d) Betz Corp., 445 State St., Hammond, Ind.
(A,B:a,b,c,d) Drayer-Hanson, Inc., 3301 Medford St., Los Angeles 33, Cal.
(A,B:a,b,c,d) Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
(A,B:d) McQuay, Inc., 1600 Broadway, N.E., Minneapolis 13, Minn. *(p. 203)*
(A,B:b) Marlo Coil Co., 6135 Manchester Ave., St. Louis 10, Mo. *(p. 205)*
(A,B) D. J. Murray Mfg. Co., 1024-3rd St., Wausau, Wis.
(A,B:e) Niagara Blower Co., 405 Lexington Ave., N.Y.C. 17 *(p. 91)*
(A,B:b) Peerless of America, Inc., 2901 Lawrence Ave., Chicago 25, Ill.
(A,B:a,b,c,d) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(A,B: a,b,d) Refrigeration Appliances, Inc., 917 W. Lake St., Chicago 7, Ill.
(A,B:b,d) Refrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
(A,B:d) Refrigeration Engrg., Inc., 7250 E. Slauson Ave., Los Angeles, Cal. *(p. 211)*
(A,B: a,b,c,d,e,f,g) St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
(A:d) Sterling Mfg. Co., 2523 Farnam St., Omaha, Neb.
(g) Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal
(d) Tenney Engrg., Inc., 26 Ave. B, Newark 5, N.J.
(A,B:a,b) Vilter Mfg. Co., 224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
(A,B:a,c) XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

UNIVERSAL JOINTS (See also FLEXIBLE COUPLINGS)

Chicago Die Casting Mfg. Co., 2500 W. Monroe St., Chicago 12, Ill.
Spicer Mfg. Co., 4100 Bennett Rd., Toledo 1, O.

V-BELTS (See BELTS & BELTING)

VALVE DISCS, FLAPPERS, REEDS, WAFERS, etc.

Acme Industrial Co., 205 N. Laflin St., Chicago 7, Ill.
Chicago Seal Co., 232 S. Hoyne Ave., Chicago 20, Ill.
Cooper-Bessemer Corp., Mt. Vernon, O.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
Henry Disston & Sons, Inc., Tacony, Phila. 35, Pa.
Durabla Mfg. Co., 114 Liberty St., N.Y.C. 6
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Jenkins Bros., 80 White St., N.Y.C. 13
Leslie Co., Valley Brook & Grant Ave., Lyndhurst, N.J.
Sandvik Steel, Inc., 111-8th Ave., N.Y.C. 11
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
J. H. H. Voss Co., 785 E. 144th St., N.Y.C. 54
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*

VALVE PACKINGS (See PACKING)

VALVE PARTS (See also NEEDLES; also SEATS, etc.

Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
Henry Disston & Sons, Inc., Tacony, Phila. 35, Pa. (Discs)
Jenkins Bros., 80 White St., N.Y.C. 13
J. H. H. Voss Co., 785 E. 144th St., N.Y.C. 54

VALVE POSITIONERS

Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
Moore Products Co., H & Lycoming Sts., Phila. 24, Pa.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.

VALVES (See particular type under type name or following)

VALVES, AIR

Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 28, Pa.
Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Consolidated Brass Co., 139 Summit, Detroit 9, Mich.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Darling Valve & Mfg. Co., Foot Walnut St., Williamsport, Pa.
Durabla Mfg. Co., 114 Liberty St., N.Y.C. 6
Gas & Oil Industry Labs., Inc., 4 Paine Ave., Irvington 11, N.J.
Gorton Heating Corp., Cranford, N.J.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Jenkins Bros., 80 White St., N.Y.C. 13
Kennedy Valve Mfg. Co., Elmira, N.Y.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Nordstrom Valve Div., Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
C. A. Norgren, 222 Santa Fe Drive, Denver, Colo.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.
John Simmons Co., Inc., 50 Church St., N.Y.C. 7
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y
Walworth Co., 60 E. 42nd St., N.Y.C. 17

VALVES, AMMONIA

Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago 7, Ill. *(p. 50)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Frick Co., Waynesboro, Pa. *(p. 44)*
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Henry Valve Co., Melrose Park, Ill. *(p. 212)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119)*

VALVES, ANGLE, GATE, GLOBE, etc.

Automatic Temperature Control Co., Inc., 5212 Pulaski Ave., Phila. 44, Pa.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, O.
Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.

(Continued)

VALVES, ANGLE, GATE, GLOBE, etc. (Continued)

Thomas Beckett & Co., Inc., P.O. Box 7354, Dallas 2, Tex.
L. J. Bordo Co., Inc., 115 New St., Glenside, Pa.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
James B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Darling Valve & Mfg. Co., Foot Walnut St., Williamsport, Pa.
Edward Valves, Inc., Subsidiary of Rockwell Mfg. Co., 1200 W. 145 St., E. Chicago, Ind.
Fairbanks Co., 393 Lafayette, N.Y.C. 3
Flori Pipe Co., 601 E. Red Bud Ave., St. Louis, Mo.
Frick Co., Waynesboro, Pa. *(p. 44)*
B. F. Goodrich Co., 500 S. Main St., Akron. O.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I
Hancock Valve Div., Manning, Maxwell & Moore, Inc., Bridgeport 2, Ct.
Henry Valve Co., Melrose Park, Ill. *(p. 212)*
Jarecki Mfg. Co., 1345 W. 12th St., Erie, Pa.
Jenkins Bros., 80 White St., N.Y.C. 13
Jerguson Gage & Valve, 87 Fellsway, Somerville, Mass.
Kennedy Valve Mfg. Co., Elmira, N.Y.
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Klingerit, Inc., 16 Hudson St., N.Y.C. 13
Ludlow Valve Mfg. Co., Inc., Foot of Adams St., Troy, N.Y.
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin'ti. 14, O.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Manning, Maxwell & Moore, Inc., Watertown 72, Mass.
Marsh Heating Equip. Co., 3501 Howard St., Skokie, Ill.
National Lead Co., 111 Broadway, N.Y.C. 6 (Lead & Lead-lined)
Northern Indiana Brass Co., 935 Plum St., Elkhart, Ind.
H. K. Porter & Co., Inc., 49th & Harrison Sts., Pittsburgh 1, Pa.
Strong, Carlisle & Hammond Co., 1392 W. 3rd St., Cleveland 13, O.
Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 214)*
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y.
Trane Co., La Crosse, Wis. *(p. 12)*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Henry Vogt Machine Co., 10th & Ormsby St., Louisville 10, Ky.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
White Flomatic Corp., P.O. Box 267, Hoosick Falls, N.Y
S. S. White Dental Mfg. Co., 10 E. 40th St., N.Y.C.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

VALVES, CARBON DIOXIDE

Bastian-Blessing Co., 4101 W. Peterson Ave., Chicago 40, Ill.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Frick Co., Waynesboro, Pa. *(p. 44)*
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
S. S. White Dental Mfg. Co., 10 E. 40th St., N.Y.C.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
York Corp., York, Pa. *(p. 119)*

VALVES, CHECK, AIR, WATER (See CHECK VALVES)

VALVES, CHECK, REFRIGERANT (See CHECK VALVES, REFRIGERANT)

VALVES, COMPRESSOR SHUT-OFF

Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Henry Valve Co., Melrose Park, Ill. *(p. 212)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Jenkins Bros., 80 White St., N.Y.C. 13
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Metrex Valve Co., 9900 Franklin Ave., Franklin Park, Ill.
Mueller Brass Co., Port Huron, Mich.
Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 214)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

VALVES, CYLINDER

Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Darling Valve & Mfg Co., Foot Walnut St., Williamsport, Pa.
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Mueller Brass Co., Port Huron, Mich.
Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 214)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.

VALVES, EXPANSION (See EXPANSION VALVES)

VALVES, FLOAT, REFRIGERANT (See HIGHSIDE FLOATS; also LOWSIDE FLOATS)

VALVES, FLOAT, WATER (See FLOAT VALVES, WATER)

VALVES, FOOT

Jas. B. Clow & Sons, 201 N. Talman Ave., Chicago 12, Ill.
Cochrane Corp., 17th St. below Allegheny Ave., Phila. 32, Pa.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill. *(p. 105)*
Deming Co., 884 S. Broadway, Salem, O.
Grove Regulator Co., 6529 Hollis St., Oakland, Cal.
Jacuzzi Bros., Inc., 5327 Jacuzzi Ave., Richmond, Cal.
Jenkins Bros., 80 White St., N.Y.C. 13
Ludlow Valve Mfg. Co., Inc., Foot of Adams St., Troy, N.Y.
A. Y. McDonald Mfg. Co., 12th & Pine Sts., Dubuque, Ia.
Swaby Mfg. Co., 3818 W. Armitage Ave., Chicago 47, Ill.
Walworth Co., 60 E. 42nd St., N.Y.C. 17
Water Cooling Corp., 71 Nassau St., N.Y.C. 7
Williams Gauge Co., 1620 Pennsylvania Ave., Pittsburgh 12, Pa.

VALVES, MOTOR OPERATED

Barber-Colman Co., Rockford, Ill.
Bristol Co., Waterbury 91, Ct.
Brown Instrument Co., Div., Minneapolis-Honeywell Regulator Co., 4414 Wayne Ave., Phila. 44, Pa.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Cutler-Hammer, Inc., 315 N. 12 St., Milwaukee 1, Wis.
Darling Valve & Mfg. Co., Foot Walnut St., Williamsport, Pa.
Davis Regulator Co., 2511 S. Washtenaw Ave., Chicago 8, Ill.
Edward Valves, Inc., Subsidiary of Rockwell Mfg. Co., 1200 W. 145 St., E. Chicago, Ind.
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Jenkins Bros., 80 White St., N.Y.C. 13

(Continued)

VALVES, MOTOR OPERATED (Continued)

Ludlow Valve Mfg. Co., Inc., Foot of Adams St., Troy, N.Y.
Lunkenheimer Co., Beekman St., & Waverly Ave., Cin'ti. 14, O.
Minneapolis-Honeywell Regulator Co., 2933-4th Ave., S., Minneapolis 8, Minn. *(p. 70)*
W. H. Nicholson & Co., 209 Oregon St., Wilkes-Barre, Pa.
Nordstrom Valve Div., Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Philadelphia Gear Wks., Inc., G St. & Erie Ave., Phila. 20 Pa.
Taylor Instrument Cos., 95 Ames St., Rochester 1, N.Y
Walworth Co., 60 E. 42nd St., N.Y.C. 17

VALVES, NEEDLE (See EXPANSION VALVES, HAND OR NEEDLE)

VALVES, PRESSURE RELIEF (See PRESSURE RELIEF VALVES)

VALVES, QUICK ACTING

Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
L. J. Bordo Co., Inc., 115 New St., Glenside, Pa.
Conoflow Corp., 2100 Arch St., Phila. 28, Pa.
Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Dersch, Gesswein & Neuert, Inc., 4845 W. Grand Ave., Chicago 39, Ill. *(p. 190)*
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R.I.
Grove Regulator Co., 6529 Hollis St., Oakland, Cal.
Hubbell Corp., P.O. Box 700, Hawley Rd., Mundelein, Ill. *(p. 189)*
J. E. Lonergan Co., 2nd & Race Sts., Phila. 6, Pa.
Lunkenheimer Co., Beekman St. & Waverly Ave., Cin'ti. 14, O.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
Paxton-Mitchell Co., 2614 Martha St., Omaha 5, Neb.
Refrigerating Specialties Co., 728 S. Sacramento Blvd., Chicago 12, Ill.

VALVES, RECEIVER

Crane Co., 836 Michigan Ave., Chicago 5, Ill. *(p. 105)*
Frick Co., Waynesboro, Pa. *(p. 44)*
Henry Valve Co., Melrose Park, Ill. *(p. 212)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Mueller Brass Co., Port Huron, Mich.
Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 214)*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.

VALVES, REFRIGERANT SHUT-OFF, NON-FERROUS

Automatic Switch Co., 41 E. 11th St., N.Y.C. 3
General Controls Co., 801 Allen Ave., Glendale 1, Cal. *(p. 67)*
Hammel-Dahl Co., 243 Richmond St., Providence 3, R.I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Henry Valve Co., Melrose Park, Ill. *(p. 212)*
Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*
Kerotest Mfg. Co., 2525 Liberty Ave., Pittsburgh 22, Pa. *(p. 213)*
Mueller Brass Co., Port Huron, Mich.
Paxton-Mitchell Co., 2614 Martha St., Omaha 5, Neb.
Superior Valve & Fittings Co., 1509 W. Liberty Ave., Pittsburgh 26, Pa. *(p. 214)*
Watson-Stillman Co., Roselle, N.J. *(p. 109)*
Weatherhead Co., 300 E. 131st St., Cleveland 8, O.

VALVES, REGULATING (See REGULATORS)

VALVES, SADDLE

Imperial Brass Mfg. Co., 537 S. Racine Ave., Chicago 7, Ill. *(p. 110)*

VALVES, SOLENOID (See SOLENOID VALVES)

VAPOR SEALS

Alfol Div., Reflectal Corp., 155 E. 44th St., N.Y.C. 17 *(p. 135)*
American Bitumuls Co., 200 Bush St., San Francisco 4, Cal.
Angier Corp., Framingham, Mass.
Benjamin Foster Co., 4635 W. Girard Ave., Phila. 31, Pa.
Lexington Supply Co., 4815 Lexington Ave., Cleveland 3, O.
Munn and Steele, Inc., 130 Lister Ave., Newark 5, N.J.
Sisalkraft Co., 205 W. Wacker Dr., Chicago 6, Ill.
Stancal Asphalt & Bitumuls Co., 200 Bush St., San Francisco 22, Cal.

VARIABLE SPEED TRANSMISSIONS (See SPEED CHANGERS)

VARNISHES, INSULATING

General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Grand Rapids Varnish Corp., 1350 Steele Ave., S.W., Grand Rapids 2, Mich.
A. C. Horn Co., Inc., 43-36-10th St., Long Island City, N.Y.
Maas & Waldstein Co., 438 Riverside Ave., Newark 4, N.J.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Sherwin-Williams Co., 101 Prospect Ave., N.W., Cleveland, O.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.

VARNISHES, PLASTIC (See also FINISHES)

General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Grand Rapids Varnish Corp., 1350 Steele Ave., S.W., Grand Rapids 2, Mich.
Interchemical Corp., 57 State St., Newark, N.J.

Maas & Waldstein Co., 438 Riverside Ave., Newark 4, N.J.
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Sherwin-Williams Co., 101 Prospect Ave., N.W., Cleveland, O.
Vita-Var Corp., 1180 Raymond Blvd., Newark 2, N.J.

VEGETABLE REFRIGERATORS (See DISPLAY CASES)

VENDING MACHINES, REFRIGERATED

Artkraft Mfg. Corp., Kibby St. & D.T.&I.R.R., Lima, O.
Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 40, Ill.
Cole Products Corp., 39 La Salle St., Chicago 3, Ill.
General Vending Machine Corp., 549 W. Washington Blvd., Chicago 6, Ill.
Healthflow, Inc., Barnett Bank Bldg., Jacksonville 2, Fla.
Hudson Products Co., Inc., 4400 St. Aubin, Detroit 7, Mich.
Hupp Corp., Refrigeration Products Div., 1250 W. 76th St., Cleveland 2, O.
Interstate Engrg. Corp., 2250 E. Imperial Highwy., El Segundo, Cal.
O. D. Jennings & Co., 4309 W. Lake St., Chicago 24, Ill.
Mills Industries, Inc., 4100 W. Fullerton Ave., Chicago 39, Ill. *(p. 60)*
Revco, Inc., Deerfield, Mich.
Spacarb, Inc., 311 E. 23rd St., N.Y.C. 10
Vendorlator Mfg. Co., 4000 Railroad, Fresno, Cal.
Wooster Brass Co., 1415 E. Bowman St., Wooster, O.

VENEERS (See PLYWOOD)

VENTILATORS & VENTILATING SYSTEMS

Acme Equip. Co., 205 E. B'way, Muskogee, Okla.
Air Devices, Inc., 17 E. 42nd St., N.Y.C. 17
Allen Ventilator Div., Production Planning Co., 704 Woodward, Rochester, Mich.
American Larson Ventilating Co., 1004 Keystone Bldg., Pittsburgh 22, Pa.
Arex Co., 333 N. Michigan Ave., Chicago 1, Ill.
Bishop & Babcock Mfg. Co., 4901 Hamilton Ave., N.E., Cleveland 14, O.
R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Burt Mfg. Co., 932 S. High St., Akron 11, O.
Chelsea Fan & Blower Co., Inc., 1206 Grove St., Irvington 11, N.J. *(p. 97)*
Electrovent Fan & Mfg. Co., 812 W. Lake St., Chicago 7, Ill.
Emerson Elec. Mfg. Co., 8100 Florissant Ave., St. Louis 21, Mo.
Hart & Cooley Mfg. Co., 500 E. 8th St., Holland, Mich.
Hartzell Propeller Fan Co., Div. of Castle Hills Corp., 910 S. Downing St., Piqua, O.
Ilg Elec. & Ventilating Co., 2850 N. Crawford Ave., Chicago 41, Ill.
King Co., 902 N. Cedar St., Owatonna, Minn.
Knowles Mushroom Ventilator Co., 583 Upper Mountain Ave., Upper Montclair, N.J.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Lockjoint Wood Products Co., 1721 Mildred Ave., Wichita 7, Kan.
Martin Fan & Blower Co., 4634 W. 21st Place, Chicago 50, Ill.
Herman Nelson Corp., 1824-3rd Ave., Moline, Ill.
John J. Nesbitt, Inc., Phila. 36, Pa. *(p. 11)*
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
B. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Readville St., Boston 36, Mass. *(p. 16)*
O. A. Sutton Corp., KFH Bldg., Wichita, Kan.
Trane Co., La Crosse, Wis. *(p. 12)*
U. S. Register Co., 344 E. Burnham St., Battle Creek, Mich.

VENTILATORS, CEILING & ROOF

Acme Equip. Co., 205 E. B'way, Muskogee, Okla.
Allen Ventilator Div., Production Planning Co., 704 Woodward, Rochester, Minn.
R. H. Bishop & Co., 103 N. 2nd St., Champaign, Ill.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Swartwout Co., 18511 Euclid Ave., Cleveland 12, O.

VENTILATORS, LOUVRE

Arex Co., 333 N. Michigan Ave., Chicago 1, Ill.
Buffalo Forge Co., 217 Mortimer St., Buffalo, N.Y. *(p. 93)*
Burt Mfg. Co., 932 S. High St., Akron 11, O.
Chelsea Fan & Blower Co., Inc., 1206 Grove St., Irvington 11, N.J. *(p. 97)*
Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
"Frigid" Fans, Div. of Circulators & Devices Mfg. Corp., 22 Rose St., N.Y.C. 7
International Metal Products Co., 500 S. 15th St., Phoenix, Ariz.
Lockjoint Wood Products Co., 1721 Mildred Ave., Wichita 7, Kan.
Maysteel Products, Inc., 740 N. Plankinton Ave., Milwaukee 3, Wis.
Milcor Steel Co., Milwaukee, Wis.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
U. S. Register Co., 344 E. Burnham St., Battle Creek, Mich.

VENTILATORS, WINDOW

Acme Equip. Co., 205 E. B'way, Muskogee, Okla.
Burt Mfg. Co., 932 S. High St., Akron 11, O.
Chelsea Fan & Blower Co., Inc., 1206 Grove St., Irvington 11, N.J. *(p. 97)*
Ilg Elec. & Ventilating Co., 2850 N. Crawford Ave., Chicago 41, Ill.
Lau Blower Co., 2007 Home Ave., Dayton 7, O.
Lockjoint Wood Products Co., 1721 Mildred Ave., Wichita 7, Kan.
Martin Fan & Blower Co., 4634 W. 21st Place, Chicago 50, Ill.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Piqua Machine & Mfg. Co., Young & Coolidge Sts., Piqua, O.
Pleasantaire Corp., 14th & K Sts., N.W., Washington 5, D.C.
Premium Plastics, Inc., 625 Salem Ave., Dayton 6, O.
O. A. Sutton Corp., KFH Bldg., Wichita, Kan.
Trane Co., La Crosse, Wis. *(p. 12)*
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.

VENTS, AIR

Climax Engrg. Co., Controls Div., 15 N. Cincinnati, Tulsa, Okla.
Maid-O'-Mist, Inc., 3217 N. Pulaski Rd., Chicago 41, Ill.
Paasche Airbrush Co., 1909 Diversey Pkwy., Chicago 14, Ill.
Premium Plastics, Inc., 625 Salem Ave., Dayton 6, O.
St. Louis Blow Pipe & Heater Co., Inc., Div. of Skinner Heating & Ventilating Co., Inc., 1948 N. 9th St., St. Louis 6, Mo.
U. S. Gypsum Co., 300 W. Adams St., Chicago 6, Ill.
U. S. Register Co., 344 E. Burnham St., Battle Creek, Mich.
J. A. Zurn Mfg. Co., Erie, Pa.

VESSELS, PRESSURE (See PRESSURE VESSELS)

VIBRATION ABSORBERS, LINE

American Brass Co., Waterbury 88, Ct. *(p. 199)*
Atlantic Metal Hose Co., Inc., 123 W. 64th St., N.Y.C. 23
Barco Mfg. Co., 1801 Winnemac Ave., Chicago 40, Ill.
Chicago Metal Hose Corp., Maywood, Ill.
Eclipse Aviation Metal Hose Dept., Div. of Bendix Aviation Corp., Phila. 44, Pa.
Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.

(Continued)

VIBRATION ABSORBERS, LINE (Continued)

Finn & Co., 2850-5th Ave., N.Y.C. 30
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Johnson Metal Hose Co., 226 Mill St., Waterbury 88, Ct.
Kelvinator Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit, Mich. *(p. 59)*
Packless Metal Products Corp., 31 Winthrop Ave., New Rochelle, N.Y. *(p. 217)*
Resistoflex Corp., 39 Plansoen St., Belleville 9, N.J.
Seamlex Co., Inc., 4123-24th St., Long Island City 1, N.Y.
Techniflex Corp., 53 Jersey St., Port Jervis, N.Y.

VIBRATION ABSORBING BASES & MOUNTINGS

Apex Molded Products Co., 3574 Ruth St., Phila. 34, Pa.
Armstrong Cork Co., Lancaster, Pa. *(p. 131)*
Barry Corp., 179 Sydney St., Cambridge 39, Mass.
Beltron Associates, Inc., 225 Lafayette St., N.Y.C. 12
Bishop & Babcock Mfg. Co., 4901 Hamilton Ave., N.E., Cleveland 14, O.
Bushings, Inc., 4358 Coolidge Highwy., Royal Oak, Mich.
Cork Import Corp., 39 Park Place, Englewood, N.J.
Cork Insulation Co., Inc., 155 E. 44th St., N.Y.C. 17
Felters Co., 210 South St., Boston 1, Mass.
Finn & Co., 2850-5th Ave., N.Y.C. 30
Firestone Industrial Products Co., 1200 Firestone Pkwy., Akron 17, O.
General Tire & Rubber Co., Garfield St., Wabash, Ind. *(p. 177)*
B. F. Goodrich Co., 500 S. Main St., Akron, O
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, O.
Goshen Rubber & Mfg. Co., Box 517, Goshen, Ind.
Hobsite Products Co., 835 River St., Paterson, N.J.
Johns-Manville, 22 E. 40th St., N.Y.C. 16 *(p. 128)*
Robt. A. Keasbey Co., 139 W. 19th St., N.Y.C. 11
Korfund Co., Inc., 48-51-32nd Place, Long Island City 1, N.Y.
Lord Mfg. Co., 1635 W. 12th St., Erie, Pa.
MB Mfg. Co., Inc., 1060 State St., New Haven 11, Ct.

Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
Rector Mineral Trading Corp., 16 E. 43rd St., N.Y.C. 17 *(p. 138)*
Rubatex Div., Great American Industries, Bedford, Va. *(p. 137)*
Sponge Rubber Products Co., Howe Ave., Shelton Ct.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Vibrashock Div., Robinson Aviation, Inc., Teterboro, N.J.
Vibration Eliminator Co., 10-28-47th Ave., Long Island City 1, N.Y.
Viking Air Conditioning Corp., 5600 Walworth Ave., Cleveland 2, O.

VOLTMETERS (See METERS, ELECTRIC)

WALK-IN COOLERS

(A—Self-contained; B—With coils but without condensing unit; C—No coils or condensing unit)

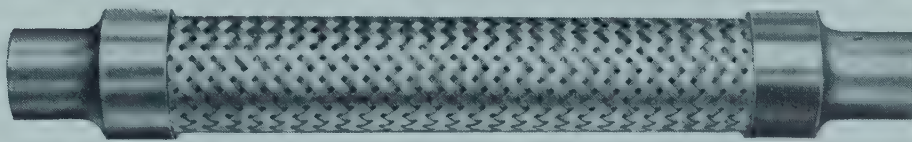
Allied Store Equip. Co., 116 N. 7th St., Minneapolis, Minn.
Amana Society, Amana, Ia.
(A,B) American Refrigeration Corp., 2836 Colfax Ave., S. Minneapolis 8, Minn.
(A,B) Annapolis Yacht Yard, Box 791, Annapolis, Md. *(p. 216)*
Bally Case & Cooler Co., Bally, Pa.
(A) Bowser, Inc., Terryville, Ct. (Industrial)
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
(C) Corbin Cabinet Lock Co., Div. of American Hardware Corp., New Britain, Ct.
(A,B) Cruse Refrigerator Co., Inc., 504 W. Main St., Louisville 2, Ky.
(A,B,C) Delaware Refrigeration Co., 834 N. 6th St., Phila 23, Pa.
(A,C) Esco Cabinet Co., West Chester, Pa.
(A,B,C) Evans Mfg. Corp., 460 S. 10th Ave., Mt. Vernon, N.Y.
(B,C) Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
(A,B,C) Fleetwood-Airflow, Inc., 421 N. Penna Ave., Wilkes-Barre, Pa.
(A,B,C) Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.
(A,B) Ed Friedrich, Inc., 1117 E. Commerce St., San Antonio 6, Tex.
(A) Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
(A,B,C) Gem Refrigerator Co., 2539 Germantown Ave., Phila. 33, Pa.
(B) John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
(A,B,C) Herrick Refrigerator Co., 1019 Commercial St., Waterloo, Ia. *(p. 170)*
(A,P) C. V. Hill & Co., Inc., 360 Pennington Ave., Trenton 1, N.J.
(B) Hussmann Refrigeration, Inc., 2401 N. Leffingwell, St. Louis 6, Mo. *(p. 81)*
(A,B,C) Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
(A,B,C) La Crosse Cooler Co., 2809 Losey Blvd., S., La Crosse, Wis.
(A,B,C) Jack Langston Co., 3700 Elm St., Dallas 1, Tex
(A,B,C) Lingle Refrigerator Co., Inc., 1116 E. 15th St., Kansas City 6, Mo.
(A,B) McCall Refrigerator Corp., Hudson, N.Y.
(B) McCray Refrigerator Co., Kendallville, Ind.
(A,B,C) Masterfreeze Corp., Sister Bay, Wis.
Matthews Refrigerator & Door Co., 5103 S.E. Powell Blvd., Portland 6, Ore.
(A,B,C) Minneapolis Show Case & Fixture Co., 1009 Washington Ave., S., Minneapolis, Minn.
(A,B) Morton Show Cases, Inc., Washington Courthouse, O.
(A,B,C) John Mowat Refrigerators, 1866 Folsom St., San Francisco 3, Cal.
(A,B,C) Nanticoke Refrigerator Manufacturers, Corner Hill & Slope Sts., Nanticoke, Pa.
(A,B,C) National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
(A,B,C) Nolin Mfg. Co., Inc., 1100 Madison Ave., Montgomery 2, Ala.
(A,B,C) Nor-Lake, Inc., 2nd & Elm Sts., Hudson, Wis.
R. Perlick Brass Co., 3110 W. Meinecke Ave., Milwaukee 10, Wis.

(Continued)

flexible VIBRATION ABSORBERS

FOR THE AIR CONDITIONING AND REFRIGERATION INDUSTRIES

LIMINATE —
IBRATION
OISE
INE BREAKAGE



SPECIFY PACKLESS for your vibration absorber requirements. Purchase all your needs from the same dependable source—from the *only* manufacturer of seamless flexible bronze tubing in large diameters as well as small. Sizes 3/16″ I.D. to 10″ I.D. Packless can furnish standard units from stock, or special lengths or assemblies as required.

SPECIFY PACKLESS for the best in engineered hose units. Heat-treated seamless bronze hose for long life—High tensile bronze braid covering for extra strength—Standard sweat tube ends attached to hose with high temperature welding rod—tested at 500 lbs. sq. in. pressure (4″ and over at 250 lbs. sq. in.)—thoroughly cleaned, dried and sealed—individually packaged in labelled cartons. A quality product of superior workmanship.

SPECIFICATIONS

To Fit Copper Tubing		I.D. Flex. Hose	Overall Unit Length*	Length Flex. Hose	Length Each Fitting	Bursting Pressure P.S.I.	Part Number Female Sweat Couplings
Actual O.D.	Nominal I.D.						
¼″	⅛″	3/16″	7″	6″	½″	3500	VAF- 1
¼″	⅛″	¼″	7½″	6½″	½″	3000	VAF- 2
⅜″	¼″	5/16″	8¼″	7″	⅝″	2500	VAF- 3
½″	⅜″	⅜″	9″	7½″	¾″	2500	VAF- 4
⅝″	½″	½″	9¾″	8″	⅞″	2000	VAF- 5
¾″	⅝″	½″	10″	8″	1″	2000	VAF- 6
¾″	⅝″	¾″	11¼″	9″	1⅛″	2000	VAF- 7
⅞″	¾″	¾″	11½″	9″	1¼″	2000	VAF- 8
1⅛″	1″	1″	13″	10″	1½″	1800	VAF- 9
1⅜″	1¼″	1¼″	14¾″	11½″	1⅝″	1500	VAF-10
1⅝″	1½″	1½″	17″	13″	2″	1250	VAF-11
2⅛″	2″	2″	20″	15″	2½″	1000	VAF-12
2⅝″	2½″	2½″	24″	18″	3″	800	VAF-13
3⅛″	3″	3″	27″	20″	3½″	750	VAF-14
3⅝″	3½″	3½″	32⅝″	24″	4-5/16″	700	VAF-15
4⅛″	4″	4″	33⅜″	24″	4-11/16″	650	VAF-16
5⅛″	5″	5″	39⅜″	28″	5-11/16″	575	VAF-17
6⅛″	6″	6″	45″	31″	7″	500	VAF-18
8⅛″	8″	8″	54½″	40″	7¼″	400	VAF-19

*These standard straight length assemblies are based on flexible seamless bronze hose having *closed* corrugations, which provide for maximum flexibility in the shortest length.

The following constructions are also available:

1. Type VAM—(male copper tube ends). VAM style longer than VAF as follows: Sizes 1 to 4—¾″ longer; Sizes 5 to 11—1″ longer; Sizes 12 and up—same length.
2. Type VAP—(male pipe thread ends—iron or brass)—same length as VAF.
3. Type VAFL—(standard A.S.A. flange ends—freely floating). Available in sizes 2″ and larger.
4. 10″ I.D.—furnished in open corrugation style only.
5. Extra long lengths—for curved or unusual installations.

PACKLESS METAL PRODUCTS CORPORATION
DEPT. D. B. • 31 WINTHROP AVE., NEW ROCHELLE, N. Y.

WALK-IN COOLERS (Continued)

(A,B,C) J. P. Pfeiffer & Son, Inc., 200 N. Paca St., Baltimore 1, Md.
(B) Puffer-Hubbard Mfg. Co., Grand Haven, Mich.
(A,B,C) Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
(B) W. Allen Rogers Industries, Inc., P.O. Box 272, Demopolis, Ala.
(A,B) C. Schmidt Co., John & Livingston Sts., Cin'ti. 14, O.
(B) Schwenger-Klein, Inc., 720 Bolivar Rd., Cleveland, O.
(A,B) Seeger Refrigerator Co., 850 Arcade St., St. Paul 6, Minn.
(B,C) Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
(A,B,C) Charles Q. Sherman Corp., 149 Broadway, N.Y.C. 6
Super-Cold Corp., 1020 E. 59th St., Los Angeles 1, Cal.
(B) Tyler Fixture Corp., 1401 Lake St., Niles, Mich. *(p. 80)*
Tyson Metal Products, 6815 Hamilton Ave., Pittsburgh 8, Pa.
(A,C) Uniflow Mfg. Co., Erie, Pa.
(B) United Refrigerator Mfg. Co., Inc., 350 Robert St., St. Paul 1, Minn.
(A,B,C) Victor Products Corp., 901 Pope Ave., Hagerstown, Md.
(B) Viking Refrigerators, Inc., 7500 Wilson Ave., Kansas City 3, Mo.
(A,B,C) Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.
(A,B,C) Weber Showcase & Fixture Co., Inc., P.O. Box 2018, Los Angeles 54, Cal.
(A,B,C) Wilson Cabinet Co., Inc., Smyrna, Del.

WALK-IN FREEZERS (See also FARM & HOME FREEZERS)

Amana Society, Amana Ia.
American Refrigeration Corp., 2836 Colfax Ave., S. Minneapolis 8, Minn.
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
Delaware Refrigeration Co., 834 N. 6th St., Phila. 23, Pa.
Esco Cabinet Co., West Chester, Pa.
Evans Mfg. Corp., 460 S. 10th St., Mt. Vernon, N.Y.
Federal Refrigerator Mfg. Co., 550 Elizabeth St., Waukesha, Wis.
Fogel Refrigerator Co., 5400 Eadom St., Phila. 37, Pa.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
John Herrel & Sons Co., 244 Lear St., Columbus 6, O.
C. V. Hill & Co., Inc., 360 Pennington Ave., Trenton 1, N.J.
Jordon Refrigerator Co., 235 N. Broad St., Phila. 7, Pa.
Jack Langston Co., 3700 Elm St., Dallas 1, Tex.
Lingle Refrigerator Co., Inc., 116 E. 15th St., Kansas City 6, Mo.
Masterfreeze Corp., Sister Bay, Wis.
National Refrigerators Co., 827 Koeln Ave., St. Louis 11, Mo.
Orley Freezers, Inc., 680 E. Fort St., Detroit 26, Mich.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
W. Allen Rogers Industries, Inc., P.O. Box 272, Demopolis, Ala.
Sherer-Gillett Co., S. Kalamazoo Ave., Marshall, Mich.
Victor Products Corp., 901 Pope Ave., Hagerstown, Md.
Ward Refrigerator & Mfg. Co., 6501 S. Alameda St., Los Angeles 1, Cal.
York Corp., York, Pa. *(p. 119)*

WASHERS (See also particular type; also PACKING; also GASKETS)

American Nut & Bolt Fastener Co., 2029 Doerr St., Pittsburgh 12, Pa.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Behringer Metal Wks., Inc., 108 Jabez St., Newark 5, N.J.
Bossert Co., P.O. Drawer 358, Utica 1, N.Y.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Clark Bros. Bolt Co., Milldale, Ct.
Continental Diamond Fibre Co., 3 Chapel St., Newark, Del.
Darcoid Co., Inc., 145-6th Ave., N.Y.C. 13
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
Lakeside Malleable Castings Co., Racine, Wis.
Premium Plastics, Inc., 627 Salem Ave., Dayton 6, O.
Rhopac, Inc., 168 N. Clinton St., Chicago 6, Ill.
Standard-Keil Hardware Mfg. Co., Inc., 639 Broadway, N.Y.C. 12
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Whitehead Stamping Co., 1661 W. Lafayette Blvd., Detroit 16, Mich.
Wrought Washer Mfg. Co., 2253 S. Bay St., Milwaukee 7, Wis.

WASHERS, AIR (See AIR WASHERS)

WASHERS, LEATHER (See also LEATHER SPECIALTIES)

Anchor Packing Co., 401 N. Broad St., Phila. 8, Pa.
Baltimore Belting Co., 23 S. Gay St., Baltimore 2, Md.
H. N. Cook Belting Co., 401 Howard St., San Francisco 5, Cal.
Fisher Leather Belting Co., Inc., 325 N. 3rd St., Phila. 6, Pa.
E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.
Southern Belting Co., 236 Forsyth St., S.W., Atlanta 2, Ga.

WASHERS, LOCK OR SPRING

Allmetal Screw Products Co., Inc., 33 Greene St., N.Y.C. 13
American Nut & Bolt Fastener Co., 2029 Doerr St., Pittsburgh 12, Pa.
Autoscrew Co., 216 W. 18th St., N.Y.C. 11
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Detroit Stamping Co., 418 Midland Ave., Detroit 3, Mich. *(p. 29)*
H. M. Harper Co., 2620 W. Fletcher St., Chicago 18, Ill.
Lamson & Sessions Co., 1971 W. 85th St., Cleveland 2, O.
Philadelphia Steel & Wire Corp., 5250 Belfield Ave., Phila. 44, Pa.
Phoenix Specialty Mfg. Co., Inc., 80 Albany Ave., Freeport, Long Island, N.Y.
St. Louis Screw & Bolt Co., 6900 N. Broadway, St. Louis 15, Mo.
Shakeproof, Inc., 2501 N. Keeler Ave., Chicago 39, Ill.
Stronghold Screw Products, Inc., 216 W. Hubbard St., Chicago 10, Ill.
Thompson-Bremer & Co., 1640 W. Hubbard St., Chicago 22, Ill.
Wrought Washer Mfg. Co., 2253 S. Bay St., Milwaukee 7, Wis.

WASHERS, RUBBER (See RUBBER PRODUCTS)

WASHERS, THRUST

Aetna Ball & Roller Bearing Co., 4600 Schubert Ave., Chicago 39, Ill.
Cleveland Graphite Bronze Co., 17000 St. Clair Ave., Cleveland 10, O.
Whitehead Stamping Co., 1661 W. Lafayette Blvd., Detroit 16, Mich.
Wrought Washer Mfg. Co., 2253 S. Bay St., Milwaukee 7, Wis.

WATER COILS (See AIR CONDITIONING COILS)

WATER COOLERS (See also particular type; also DRINKING WATER COOLERS)

WATER COOLERS, ATMOSPHERIC (See COOLING TOWERS)

WATER COOLERS, BAUDELOT TYPE

Baker Refrigeration Corp., S. Windham, Me. *(p. 48)*
Burge Ice Machine Co., 218 N. Jefferson St., Chicago 6, Ill.
Chester-Jensen Co., Fifth & Tilghman Sts., Chester, Pa.

(Continued)

ACME INDUSTRIES, INC.

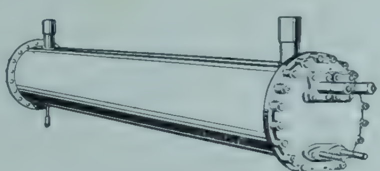
Jackson, Michigan

Representatives in Principal Cities

Continuously Serving The Refrigeration Industry Since 1919

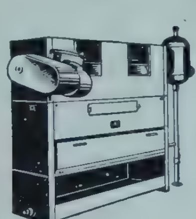
FREON CONDENSERS
AMMONIA CONDENSERS

Shell and Tube type for use with Ammonia, Freon or other Refrigerants. Standard or special designs to meet varying water temperatures available and condensing temperatures desired.



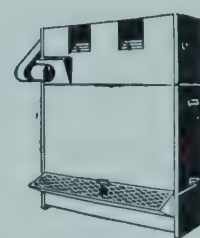
DRY-EX COOLERS

Refrigerant in Tubes, solution baffled through shell. For cooling water, brine, glycols or alcohols by direct expansion of refrigerant.



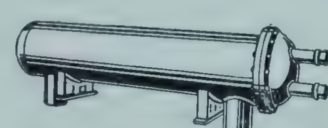
BLO-COLD INDUSTRIAL UNIT COOLERS

Blo-Cold Models are available for either medium temperature or low-temperature applications. *All fabricated steel parts are hot-dip galvanized after fabrication.*



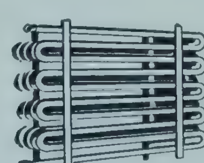
EVAPORATIVE CONDENSERS AND COOLING TOWERS

All prime surface for Freon or Ammonia Refrigerants—Heavy gage sheet metal casings, especially processed for maximum resistance to rust and corrosion. Capacities to 100 tons. *All fabricated steel parts are now hot-dip galvanized after fabrication.*



HEAT INTERCHANGERS

Shell and Coil units for small capacities, shell and tube units for large installations. 16 standard models from one ton to 180 tons capacity.



PIPE COILS

Fabricated in all shapes and sizes from ½ in. IPS to 2 in. IPS., in accordance with customer's specifications.

Acme Industries, Inc. also manufacture Flooded Water and Brine Coolers, Oil Separators, "Flow-Cold" Liquid Chillers, Heat Exchangers, Receivers and Fin Coils

WRITE FOR CATALOG ON ANY PRODUCT

WATER COOLERS, BAUDELOT TYPE (Continued)

Frick Co., Waynesboro, Pa. *(p. 44)*
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Nooter Corp., 1426 S. 2nd St., St. Louis 4, Mo.
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Stewart Ice Machine Co., 1282 W. 1st St., Pomona, Cal.
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
York Corp., York, Pa. *(p. 119)*

WATER COOLERS, DRY EXPANSION

Acme Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p 219)*
Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Ill.
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 *(p. 122)*
King-Zeero Co., 1447 Montrose Ave., Chicago 13, Ill. *(p. 149)*
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55)*
Reco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
Richmond Engrg. Co., Inc., 7th & Hospital Sts., Richmond 19, Va.
Standard Heater & Oil Equip. Co., 245 Cornelison Ave., Jersey City 2, N.J.
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.

WATER COOLERS, SHELL & COIL

Acme Industries, Inc., Mechanic & Ganson Sts Jackson, Mich. *(p. 219*
Richard M. Armstrong Co., Box 188, W. Chester, Pa *(p. 52*
Bell & Gossett Co., 8200 Austin Ave., Morton Grove, Il
Carrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45*
Doyle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32 N.Y. *(p. 56*
Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5 N.Y. *(p. 220*
Frick Co., Waynesboro, Pa. *(p. 44*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Interstate Engrg. Corp., 2250 E. Imperial Highwy., E Segundo, Cal.
L. O. Koven & Brother, Inc., 154 Ogden Ave., Jersey Cit 7, N.J.
Patterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55*
Potter & Rayfield, Inc., P.O. Box 1042, Atlanta 1, Ga.
Reco Products Div., Refrigeration Engrg. Corp., 202 Naudain St., Phila. 46, Pa.
Refrigeration Economics Co., Inc., 1231 E. Tusca rawas St., Canton 4, O. *(p. 207*
Rempe Co., 340 N. Sacramento Blvd., Chicago 12, Ill.
Edw. Renneburg & Sons Co., 2639 Boston St., Baltimor 24, Md.
Standard Heater & Oil Equip. Co., 245 Cornelison Ave. Jersey City 2, N.J.
Temprite Products Corp., 47 Piquette Ave., Detroi 2, Mich. *(p. 86*
Vilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43*
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Worthington Pump & Machinery Corp., Harrison N.J. *(p. 116*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119*

ATER COOLERS, SHELL & TUBE

me Industries, Inc., Mechanic & Ganson Sts., Jackson, Mich. *(p. 219)*
chard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
ker Refrigeration Corp., Inc., S. Windham, Me. *(p. 48)*
lifornia Steel Products Co., Barrett & "A" Sts., Richmond, Cal.
rrier Corp., 302 S. Geddes St., Syracuse 1, N.Y. *(p. 45)*
vis Engrg. Corp., 1064 E. Grand St., Elizabeth 4, N.J.
yle & Roth Mfg. Co., Foot 23rd St., Brooklyn 32, N.Y. *(p. 56)*
ltrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
ick Co., Waynesboro, Pa. *(p. 44)*
y Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
ramer Trenton Co., Olden & Breuning Aves., Trenton 5, N.J. *(p. 202)*
mmus Co., 420 Lexington Ave., N.Y.C.
arley Co., Inc., 3001 Fairfax Rd., Kansas City 15, Mo. *(p. 75)*
atterson-Kelley Co., Inc., E. Stroudsburg, Pa. *(p. 55)*
eco Products Div., Refrigeration Engrg. Corp., 2020 Naudain St., Phila. 46, Pa.
efrigeration Economics Co., Inc., 1231 E. Tuscarawas St., Canton 4, O. *(p. 207)*
ichmond Engrg. Co., Inc., 7th & Hospital Sts., Richmond 19, Va.
oss Heater & Mfg. Co., Div. of American Radiator & Standard Sanitary Corp., Buffalo 13, N.Y.
tandard Heater & Oil Equip. Co., 245 Cornelison Ave., Jersey City 2, N.J.
. F. Sturtevant Div., Westinghouse Elec. Corp., 101 Reading St., Boston 36, Mass. *(p. 16)*
rane Co., La Crosse, Wis. *(p. 12)*
yphoon Air Conditioning Co., Inc., Div. of Ice Air Conditioning Co., Inc., 794 Union St., Brooklyn 51, N.Y.
ilter Mfg. Co., 2224 S. 1st St., Milwaukee 7, Wis. *(p. 43)*
Whitlock Mfg. Co., Drawer 390, Hartford 1, Ct.
Wittenmeier Machinery Co., 850 N. Spaulding Ave., Chicago 51, Ill.
Worthington Pump & Machinery Corp., Harrison, N.J. *(p. 116)*
XL Refrigerating Co., 1834 W. 59th St., Chicago 36, Ill.
York Corp., York, Pa. *(p. 119)*

WATER GAUGE COLUMNS (See GAUGE GLASSES)

WATER HEATERS

Richard M. Armstrong Co., Box 188, W. Chester, Pa. *(p. 52)*
Electric Heater Co., Woodend Rd., Stratford, Ct.
Frigidaire Div., Gen'l. Motors Corp., Dayton 1, O. *(p. 6)*
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Leonard Div., Nash-Kelvinator Corp., 14250 Plymouth Rd., Detroit 32, Mich.
Patterson-Kelley Co., E. Stroudsburg, Pa. *(p. 55)*
Rheem Mfg. Co., 570 Lexington Ave., N.Y.C. 22
Servel, Inc., Evansville 20, Ind.
A. O. Smith Corp., 3533 N. 27th St., Milwaukee 1, Wis.
David Stout & Sons, 7016 Manchester Blvd., St. Louis 17, Mo.
Wilson Cabinet Co., Inc., Smyrna, Del.

WATER STRAINERS (See STRAINERS)

WATER TREATING & TESTING EQUIPMENT & MATERIALS (See also INHIBITORS, CORROSION)

American Sand-Banum Co., Inc., 9 Rockefeller Plaza, N.Y.C. 20
American Water Softener Co., S.E. Corner 4th & Lehigh Ave., Phila. 33, Pa.
Aquatic Chemical Labs., Inc., 95 Liberty St., N.Y.C.
Bello Industrial Equip. Div., Bogue Elec. Co., 37 Kentucky Ave., Paterson, N.J.
Calgon, Inc., Hagan Bldg., Pittsburgh 30, Pa.
Chemical Engrg. Co., P.O. Box 1076, Dallas, Tex.

(Continued)

WATER TREATING & TESTING EQUIPMENT & MATERIALS (Continued)

Chemical Solvent Co., Box 487, Birmingham, Ala.
Cochrane Corp., 17th St. below Allegheny Ave., Phila. 32, Pa.
Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill.
Doctor Boiler, Inc., 4316 Main St., Dallas, Tex.
Dow Chemical Co., Midland, Mich.
Elgin Softener Corp., Elgin, Ill.
Ferro-Nil Corp., 381-4th Ave., N.Y.C. 16
Filter Paper Co., 2450 S. Michigan Ave., Chicago 16, Ill.
Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. (p. 220)
Graver Water Conditioning Co., 216 W. 14th St., N.Y.C. 11
D. W. Haering & Co., P.O. Box 6037, Harlandale Station, San Antonio, Tex.
D. W. Haering & Co., P.O. Box 6037, Dallas, Tex.
Hungerford & Terry, Inc., 226 Atlantic Ave., Clayton, N.J.
Infilco, Inc., 325 W. 25th St., Chicago 16, Ill.
Lehigh Fan & Blower Co., 128 Linden St., Allentown, Pa.
Loomis-Manning Filter Co., Schuylkill Ave. below Reed St., Phila. 46, Pa.
Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.
Mueller Steam Specialty Co., Inc., 40-20-22nd St., Long Island City 1, N.Y.
Mutual Chemical Co. of America, 270 Madison Ave., N.Y.C. 16
National Aluminate Co., 6216 W. 66th Place, Chicago 38, Ill. (p. 221)
North American Fibre Products Co., Standard Bldg., Cleveland 13, O.
Oakite Products, Inc., 22 Thames St., N.Y.C. 6
O'Brien Industries, 84 Bishop St., Jersey City 4, N.J.
Oshkosh Filter & Softener Co., 51 Ceape St., Oshkosh, Wis.
Paul Pumps, Inc., 1700 N. Harrison St., Fort Wayne 7, Ind.
Permutit Co., 330 W. 42nd St., N.Y.C. 18
Pittsburgh Plate Glass Co., 632 Duquesne Way, Pittsburgh 22, Pa.
Milton Roy Co., 1401 E. Mermaid Ave., Phila. 18, Pa.
Sta-Rite Products, Inc., Delavan, Wis.
F. J. Stokes Machine Co., Tabor Rd., Phila. 20, Pa.
Tempo Chemical Co., Inc., 4-88—47th Ave., Long Island City 1, N.Y.
Water Service Labs., Inc., 423 W. 126th St., N.Y.C. 27
Western Chemical Co., 713 Washington St., Kansas City 6, Mo.
Wilbur-Williams Co., 43 Leon St., Boston, Mass.
Wright Chemical Corp., 627 W. Lake St., Chicago 6, Ill.

Worthington Pump & Machinery Corp., Harrison, N.J. (p. 116)
York Corp., York, Pa. (p. 119)

WATTMETERS (See METERS, ELECTRIC)

WEATHER STRIP (See also DOOR GASKETS)

Brasco Mfg. Co., Harvey, Ill.
Bridgeport Fabrics Co., Bridgeport 1, Ct.
Chamberlin Co. of America, 1254 La Brosse St., Detroit 26, Mich.
W. J. Dennis & Co., 1732 N. Kolmar Ave., Chicago 39, Ill.
B. F. Goodrich Co., 500 S. Main St., Akron, O.
Koch Butchers' Supply Co., 600 E. 14th Ave., N., Kansas City 16, Mo.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N.J.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

WELDING ELECTRODES, RODS & WIRE

All-State Welding Alloys Co., Inc., 273 Ferris Ave., White Plains, N.Y.
American Brass Co., Waterbury 88, Ct. (p. 199)
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Arcos Corp., 1515 Locust St., Phila. 2, Pa. (Stainless)
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Bristol Brass Corp., Bristol, Ct.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
Driver-Harris Co., Harrison, N.J.
Eutectic Welding Alloys Corp., 40 Worth St., N.Y.C. 13
Galv-Weld Products, 324 E. 2nd St., Dayton 2, O.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Handy & Harman, 82 Fulton St., N.Y.C. 7
Hobart Bros. Co., 146 Hobart Square, Troy, O.
International Nickel Co., 67 Wall St., N.Y.C. 5 (Monel, Nickel, etc.)
Lincoln Elec. Co., 2818 Colfax Rd., Cleveland 1, O.
Linde Air Products Co., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind. (Electrodes only)
Marquette Mfg. Co., Inc., 307 E. Hennepin, Minneapolis 13, Minn.
National Carbon Co., Inc., Unit of Union Carbide & Carbon Corp., 30 E. 42nd St., N.Y.C. 17
Revere Copper & Brass, Inc., 230 Park Ave., N.Y.C 17 (p. 197)
Rex Welder & Engrg. Co., 1316 E. 10th St., Kansas City 6, Mo.
A. O. Smith Corp., 3533 N. 21st St., Milwaukee 1, Wis.
Trindl Products, Ltd., 17 E. 23rd St., Chicago 16, Ill.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.
Westinghouse Elec. Corp., 4454 Genesee St., Buffalo 5, N.Y.

WELDING ELECTRODE COOLERS (See ELECTRODE COOLING SYSTEMS)

WHEELS, BLOWER (See BLOWERS)

WINDOWS, COLD STORAGE (See COLD STORAGE DOORS & WINDOWS)

WIRE, ALUMINUM

Aluminum Co. of America, Pittsburgh 19, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Metallizing Engrg. Co., Inc., 38-14-30th St., Long Island City 2, N.Y.
Permanente Products Co., 1924 B'way, Oakland 12, Cal.
Reynolds Metals Co., 2000 S. 9th St., Louisville 1, Ky.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

WIRE, BRASS, BRONZE, COPPER, etc.

American Brass Co., Waterbury 88, Ct. (p. 199)
Bristol Brass Corp., Bristol, Ct.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
P. R. Mallory & Co., Inc., 3029 E. Washington St., Indpls., Ind.
Metallizing Engrg. Co., Inc., 38-14-30th St., Long Island City 2, N.Y.
Scovill Mfg. Co., 99 Mill St., Waterbury 91, Ct.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R.I.

WIRE, CABLE & ROPE

American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Bethlehem Steel Co., Bethlehem, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Laclede Steel Co., Arcade Bldg., St. Louis 1, Mo.
Macwhyte Wire Rope Co., 2923-14th Ave., Kenosha, Wis.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Il.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp., 500-5th Ave., N.Y.C. 18

WIRE, ELECTRIC (See also CABLE, ELECTRIC; CORDS, ELECTRIC)

American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.

(Continued)

WIRE, ELECTRIC (Continued)

Belden Mfg. Co., 4647 W. Van Buren St., Chicago, Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Ct.
General Elec. Co., 1 River Rd., Schenectady 5, N.Y.
Packard Elec. Div., Gen'l. Motors Corp., Warren, O.
Pent Elec. Co., Inc., 634 Michigan Trust Bldg., Grand Rapids 2, Mich.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
U. S. Rubber Co., 1230 Ave. of the Americas, N.Y.C. 20

WIRE, ELECTRIC RESISTANCE

Driver-Harris Co., Harrison, N.J.

WIRE, GALVANIZED

American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Bethlehem Steel Co., Bethlehem, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Laclede Steel Co., Arcade Bldg., St. Louis 1, Mo.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Tennessee Coal, Iron & Railroad Co., U. S. Steel Corp. Subsidiary, Brown-Marx Bldg., Birmingham, Ala.
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp., 500-5th Ave., N.Y.C. 18

WIRE, INCONEL, MONEL & NICKEL

Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Driver-Harris Co., Harrison, N.J.
Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.
Haynes Steellite Co., Unit of Union Carbide & Carbon Corp., Kokomo, Ind.
International Nickel Co., 67 Wall St., N.Y.C. 5

WIRE, STEEL

American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Armco Steel Corp., Middletown, O.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Bethlehem Steel Co., Bethlehem, Pa.
Laclede Steel Co., Arcade Bldg., St. Louis 1, Mo.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Youngstown Sheet & Tube Co., Youngstown, O.

WIRE, STAINLESS STEEL

Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa.
American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Arcos Corp., 1515 Locust St., Phila. 2, Pa.
Armco Steel Corp., Middletown, O.
Carpenter Steel Co., Reading, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Driver-Harris Co., Harrison, N.J.
Firth-Sterling Steel & Carbide Corp., Demmler Rd., McKeesport, Pa.
Metallizing Engrg. Co., Inc., 38-14-30th St., Long Island City 2, N.Y.
Republic Steel Corp., Republic Bldg., Cleveland 1, O.

WIRE, TINNED

American Steel & Wire Co., Rockefeller Bldg., Cleveland 13, O.
Bethlehem Steel Co., Bethlehem, Pa.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32, Ill.
Laclede Steel Co., Arcade Bldg., St. Louis 1, Mo.

WIRE, WELDING (See WELDING ELECTRODES)

WIRE CLOTH & MESH (See also MESH, METAL)

Bethlehem Steel Co., Bethlehem, Pa.
Buffalo Wire Wks., 3200 Terrace, Buffalo 2, N.Y.
Central Steel & Wire Co., 3000 W. 51st St., Chicago 32 Ill.
Chase Brass & Copper Co., 236 Grand St., Waterbury 91 Ct.
Cyclone Fence Div., American Steel & Wire Co., U. S. Steel Corp. Subsidiary, P.O. Box 260, Waukegan Ill.
Kentucky Metal Products Co., Preston St. & Audubon Park, Louisville 4, Ky.
Michigan Wire Cloth Co., 2098 Howard St., Detroit 16 Mich.
Newark Wire Cloth, 351 Verona Ave., Newark 4, N.J.
Rolock, Inc., 1350 Kings Highway, Fairfield, Ct.
Joseph T. Ryerson & Son, Inc., 16th & Rockwell Sts., Chicago, Ill.
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp., 500-5th Ave., N.Y.C. 18

WIRE FORMING, WIRE SPECIALTIES & WIRE-WORK (See also SHELVES)

American Spring & Wire Specialty Co., 816 N. Spaulding Ave., Chicago 51, Ill.
Armstrong Co., 34-36 Bell Blvd., Bayside, N.Y.
Atlantic Steel Co., P.O. Box 1714, Atlanta 1, Ga.
Buffalo Wire Wks., 3200 Terrace, Buffalo 2, N.Y.
Central Wire & Iron Wks., 621 E. Locust St., Des Moines 9, Ia.
Collis Co., Box 231, Clinton, Ia.
L. F. Grammes & Sons, Inc., 365 Union St., Allentown, Pa.
Hunter Pressed Steel Co., 801 Maple St., Lansdale, Pa.
Kentucky Metal Products Co., Preston St. & Audubon Park, Louisville 4, Ky.
Newark Wire Cloth, 351 Verona Ave., Newark 4, N.J.
Peerless Wire Goods Co., Lafayette, O.
Rolock, Inc., 1350 Kings Highway, Fairfield, Ct.
Standard-Keil Hardware Mfg. Co., Inc., 639 B'way, N.Y.C. 12
E. H. Titchener & Co., Binghamton, N.Y.
Townsend Co., 205 River Rd., New Brighton, Pa.
Union Steel Products Co., 448 Pine St., Albion, Mich. *(p. 182)*
United Steel & Wire Co., Battle Creek, Mich.
Wall Wire Products Co., 11333 General Dr., Plymouth, Mich.
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp., 500-5th Ave., N.Y.C. 18
L. A. Young Spring & Wire Corp., 9200 Russell St., Detroit 11, Mich.

WIRING DEVICES & HARNESSES

Cornish Wire Co., Inc., 15 Park Row, N.Y.C. 7
General Elec. Co., 1285 Boston Ave., Bridgeport 2, Ct.
Graybar Elec. Co., Inc., Graybar Bldg., N.Y.C. 17
Packard Elec. Div., Gen'l. Motors Corp., Warren, O.
Pent Elec. Co., Inc., 634 Michigan Trust Bldg., Grand Rapids 2, Mich.
Riverside Mfg. Co., 10221 Michigan Ave., Dearborn, Mich. *(p. 223)*
United Mfg. & Service Co., 405 W. 6th, Milwaukee, Wis.

X-RAY COOLING EQUIPMENT (See also WATER COOLERS)

Filtrine Mfg. Co., 53 Lexington Ave., Brooklyn 5, N.Y. *(p. 220)*
Gay Engrg. Co., 2730 E. 11th St., Los Angeles 23, Cal.
Heat-X-Changer Co., Inc., 415 Lexington Ave., N.Y.C. 17 *(p. 122)*
Temprite Products Corp., 47 Piquette Ave., Detroit 2, Mich. *(p.86)*

ZEOLITES

Liquid Conditioning Corp., 114 E. Price St., Linden, N.J.
Permutit Co., 330 W. 42nd St., N.Y.C. 18

ZINC

Eagle-Picher Sales Co., American Bldg., Cin'ti. 1, O.
Illinois Zinc Co., 2959 W. 47th St., Chicago 32, Ill.
Metallizing Engrg. Co., Inc., 38-14-30th St., Long Island City 2, N.Y.
National Lead Co., 111 Broadway, N.Y.C. 6
New Jersey Zinc Co., 160 Front St., N.Y.C. 7
Northwest Lead Co., 2700-16th Ave., S.W., Seattle 4, Wash.